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THE SCIENTIFIC MONTHLY

DECEMBER, 1923

THE COMMON SENSE OF THE THEORY OF RELATIVITY[1]

By Dr. PAUL R. HEYL

U. S. BUREAU OF STANDARDS

THE word gravitation can not be mentioned nowadays without bringing to mind the two names Newton and Einstein. Newton's connection with the subject is familiar to all; but what has Einstein done that his name should be mentioned in the same breath?

Let us recall briefly Newton's claim to remembrance in this connection. The explanation of the falling of bodies as due to an attractive force exerted by the earth was, of course, not original with Newton. The conception was familiar to Galileo; it was known to Aristotle. Even the law of the inverse square had suggested itself to more than one mind before the publication of the Principia. Newton's especial contribution to the subject was the conception and demonstration of the universality of gravitation according to the inverse square law as a sufficient explanation of the motion first, of the moon around the earth, then of the various planets around the sun, and, finally, by a legitimate extrapolation of the motions of every member of the stellar universe.

Every hypothesis as to the cause of things, no matter how flawless in logic and sound in mathematics, must stand the test of experiment before final acceptance. In the case of the Newtonian law of gravitation this test occupied many years and involved long-continued observations of the planets. For decade after decade the motions of these bodies were observed to follow with exquisite accuracy the paths prescribed for them by the law of inverse squares. With the passage of time not only did instruments become more perfect, but with the interval of years for comparison measurements became increasingly accurate; yet so closely had Newton cut

[1] Published by permission of the director of the Bureau of Standards of the U. S. Department of Commerce.

to the line that over a century elapsed before any serious divergence of observation from theory became noticeable. Finally, Leverrier, in 1845, called attention to the fact that the planet Mercury showed a slight irregularity in its motion, inconsistent with the law of inverse squares, and too large to be explained as an error of observation. This discrepancy has been confirmed by later astronomers. The seriousness with which it has been generally regarded is shown by the fact that all other attempts to explain this anomaly having failed, the radical proposal was made to alter slightly the Newtonian law by changing the exponent 2 to 2.000 000 1612. This was first suggested by Asaph Hall, the discoverer of the satellites of Mars, and was for some time favorably regarded by no less an authority than Newcomb, who abandoned it only after E. W. Brown showed that the motion of the moon did not allow of even this slight departure from the whole number 2. The anomalous behavior of Mercury thus remained an unexplained puzzle. The simplicity of the Newtonian law of inverse squares and its inherent reasonableness and probability on geometric considerations weighed heavily in its favor; so much so that repeated failures to account for the irregularity of Mercury by the presence of unrecognized attracting matter gave rise to a tendency in certain quarters to throw doubt on the reality of the alleged discrepancy.

Such was the state of affairs when Einstein appeared upon the scene with his now famous law of gravitation. This law had little in the way of intrinsic attractiveness to recommend it. As opposed to the simplicity which characterizes the law of Newton that of Einstein is complex in the extreme. Where Newton's law takes the form of a single differential equation, that of Einstein is expressed by a set of ten simultaneous differential equations, each of so fearful and wonderful a structure that a most compact and unfamiliar notation is required to render it fit to print. Theories far less formidable have fallen of their own weight, but that of Einstein has gradually compelled recognition, despite its repelling appearance, solely upon performance, by reason of its ability to furnish results; for it not only explained everything which the Newtonian law explained, and equally well, but it also, without forcing, explained the great puzzle of the irregularity of Mercury. Nay, more: it undertook the always precarious business of prediction, for it indicated the existence of a phenomenon hitherto unobserved, the deflection of a ray of light under the intense gravitational forces existing near the sun. This prediction has recently received the final stamp of experimental verification in the results of the 1922 eclipse expedition of the Lick Observatory. Additional weight attaches to these results from the fact that Director Campbell was known to have had no bias in Einstein's favor.

Such a record of performance on the part of a new theory demands for it the serious attention of all who profess and call themselves physicists. To obtain a proper perspective for the understanding of the subject it will be well for us to review briefly the history of the theory of gravitation.

Among the various different phenomena studied by the physicist gravitation, since the time of Newton, has stood in a class by itself. For the rest, the unification of physical phenomena has gone on apace. Heat lost its individual status as an imponderable entity (caloric), and took its place as one of the many forms of that protean concept, energy. Relations were found between magnetism and electricity, and between electricity and light. Even matter itself is now recognized as electrical in its structure. Gravitation, however, held itself aloof, steadily refusing to show any kinship to other physical phenomena. True, there is a superficial resemblance to the attraction of magnetic and of electrified bodies; but with the law of inverse squares the resemblance ends; for magnetic attraction can be cut off by a suitable screen and is greatly influenced by change of temperature; and in electrostatics we have the phenomenon of the dielectric constant, the effect of the intervening medium. Nothing of this kind obtains in gravitation. Much experimental work has been done in the hope of discovering something with which gravitation varies, but all results have been negative. Experiments with the pendulum, in the hands of Newton, and later of Bessel, have shown that gravitation is independent of the nature of the material. The precision reached in Bessel's experiments was about one part in 60,000. It is interesting to notice that among the substances tested by him were meteoric iron and meteoric stone. More recent experiments by Eötvös, with the torsion pendulum, have carried the precision to one part in two hundred million. Recent experiments at the Bureau of Standards have shown, to a precision of one part in a billion (10^9) that gravitation does not vary with the orientation of a crystal in the gravitative field of the earth. It is also known that gravitation is not a function of the temperature, and, in spite of certain recent claims to the contrary, it appears well established that the mass of the whole earth exerts no perceptible gravitational screening effect. In fact, gravitation seems to be a function of nothing but the mass involved and the space coordinates of the system.

Nor has speculation been idle. Newton, officially, in his formal publications, "framed no hypotheses"; but his letters show that privately he speculated freely, as every scientific man should. Many speculative theories as to the cause of gravitation have been propounded. The Smithsonian Annual Report for 1876 contains a collection of all the hypotheses of this nature which had found

their way into print since the time of Newton, some twenty-five or thirty in number. Since that time perhaps half a dozen more might be added, such as that proposed by Osborne Reynolds. Needless to say, none of these hypotheses is to-day of more than historical interest.

As a net result of all this theorizing and experimenting we may say that at the beginning of the twentieth century our knowledge of gravitation was just where Newton left it. Negative results there were in plenty, but nothing positive. Then came the Einstein theory, giving us the two important results before mentioned, the first positive advances in the theory of gravitation for two centuries.

The Einstein theory of gravitation may be compared to the castles of medieval Europe. Their stone walls were proof against the means of attack known in those days, yet these strongholds had always a vulnerable spot, the gateway by which they communicated with the outside world. By this gateway they were usually attacked and often taken.

And so it is with the theory in question. It is self-contained, logically consistent, and, I believe, mathematically impregnable; yet it connects with the physical world by a fundamental postulate which must, in the last analysis, be justified by experiment. If this postulate fails, the whole theory falls with it. This postulate is called the Principle of Equivalence.

I have said that gravitation is in a class by itself among physical phenomena. This is not quite true; for Einstein was the first to point out that there is another phenomenon of very much the same order, namely, inertia, especially in the form known as centrifugal force. Centrifugal force is independent of the material, is not a function of the temperature and can not be cut off by any form of screen. In fact, centrifugal force, like gravitation, seems to be a function only of the mass involved and the space (and time) coordinates of the system.

Guided by this parallelism of phenomena Einstein formulated his principle of equivalence of gravitation and inertia, their identity of nature and the consequent impossibility of distinguishing between them. In the whole history of gravitative speculation there is no parallel for this; the idea is entirely original. All previous theories had attempted in some way to account for the existence of a force drawing together the attracting bodies, usually by supposing them pressed together from without by an intercepted flux of some more or less vague description. Einstein takes absolutely new ground. Instead of trying to supply machinery for the production of a force of attraction he denies the existence of such a force. According to his theory there is no more force of attraction between the sun and the earth to hold the latter in its orbit

than there is centrifugal force of repulsion preventing it from falling into the sun. Both so-called "forces" are mathematical fictions; both are but different aspects of the one entity, inertia.

Einstein did not make this novel assumption without a certain experimental foundation. The equality, or at least the proportionality of the inert mass and the gravitational mass of a body is, as we have seen, one of the most precisely determined facts in nature; and the failure to detect any gravitational difference in crystals which are in every other respect (save inertia) anisotropic definitely puts gravitation and inertia into one class and all other crystalline properties into another. Under the Newtonian law this close proportionality or equality of inert and gravitational masses appeared only as a curious but accidental coincidence. In the Einstein theory it is the foundation stone.

The principle of equivalence is sometimes stated in formal and mathematical language as follows: "Every natural gravitative field of force is equivalent to an artificial field of inertial force resulting from a suitable change of coordinates."[2]

This is a hard saying; but such is its importance that it is worth our while attempting to arrive at a clear conception of its meaning.

According to an interview published several years ago in the daily papers, Einstein's mind was turned in this direction by witnessing an accident. The story is curiously suggestive of that of Newton and the falling apple. It appears that Einstein saw a man fall from a scaffolding, land on a pile of brush and escape without serious injury. Einstein, who appears to be of a naïve frame of mind, interviewed the victim of the accident and asked him whether, while he was falling freely through the air, he felt the pull of the earth drawing him down. A trained observer might well doubt whether his state of mind under the circumstances would be suitable for the making of scientific observations; but the person in question took Einstein seriously and assured him that he had no recollection of anything of the kind. This answer was apparently what Einstein expected. "Yes," said he, "this man's coordinates were changed from a stationary to a moving system with just the proper degree of acceleration to neutralize the gravitative pull of the earth."

Another illustration that may help us in this connection is that of an elevator. Imagine an elevator with closed walls, containing an observer. The elevator will be supposed first at rest. If a bullet be fired through the elevator walls from without, the path of the bullet will appear to the observer within as a straight line from wall to wall, though not necessarily horizontal. The same will be true if the elevator be in uniform motion. But if the elevator be

[2] Eddington: Freundlich.

in accelerated motion, say upwards, the path of the bullet will no longer appear straight, but as a curved trajectory, convex upwards. The observer might account for this curved path by saying that the bullet moved according to the resultant of two forces: its original impulse, causing by itself a straight path from wall to wall, compounded with a force of attraction of some unknown nature drawing the bullet downward toward the floor of the elevator.

Another illustration used by Einstein is that of a revolving disc. Suppose a large horizontal disc capable of carrying an observer, such as may be seen in amusement parks. Let the disc be covered by a large dome-shaped lid, so that the observer within can not tell by direct observation whether or not the disc is in rotation. Suppose the disc is at first stationary. The observer, in walking from one point to another of his little world, would perceive no difference at any point from any other. But let the disc be in rotation, and, though the observer could not directly perceive the motion, he would become aware of a difference. At every point of his space except the exact center he would experience a force repelling him radially outward; and the greater the distance from the center the greater the force of repulsion. He would, in fact, be living in a sort of turned-inside-out gravitational field. This "force" of repulsion is, however, purely inertial in its nature. Moreover, this force, being proportional to the square of the speed of rotation, will be the same whether the disc rotates in a negative or in a positive sense; but if we suppose the disc given an imaginary velocity of rotation, $v\sqrt{-1}$, the force experienced by the observer will now be proportional to $(v\sqrt{-1})^2$ or $-v^2$; in other words, the force will now be an attraction toward the center, still more closely simulating gravitation, though still strictly inertial in its origin.

Imperfect as are these illustrations as attempts to represent the actual gravitational field of a body, they nevertheless help us to understand what Einstein means by saying that a gravitative field is equivalent to an inertial field produced by a suitable change of coordinates; yet none of these suggestions furnishes us with a change of coordinates completely adequate to the representation of the actual three dimensional gravitative field of a particle. The task of finding such a coordinate system, if indeed any should exist, might well appal the best equipped of mathematicians; yet with sublime confidence in his intuition, it was to this task that Einstein set himself.

And then a wonderful thing happened; for, with but the slenderest of clues and guided principally by what we may fairly call the intuition of genius, he succeeded! He found a transformation of space and time coordinates which represents even more accu-

rately than Newton's law the actual physical phenomena of the gravitative field of a body; which fits closely the singularities in the motion of the planet Mercury and in the path of a ray of light very close to the sun; a transformation which fully justifies the bold assertion of the principle of equivalence that a natural gravitative field may be perfectly replaced by an artificial inertial field created by a change of coordinates.

And what is the nature of this new coordinate system? Is it that of a falling man, a rising elevator or a whirling disc? No, it is none of these, nor does it remotely resemble any one of them. It is a concept transcendental in the extreme, for it supposes space to be four-dimensional and non-Euclidean in character, curved or warped slightly in a fifth dimension!

Here we have another hard saying. Let us step down two dimensions to render our words mentally picturable, and consider a space of two dimensions curved in a third dimension.

Imagine a level surface of still water of indefinite extent; this surface will be two-dimensional, having length and breadth, but no thickness. The surface being perfectly flat, the geometry of figures traced upon it will be Euclidean, that is to say, the sum of the angles of a triangle will be exactly 180°, and through a given point only one parallel can be drawn to a given straight line. But suppose the surface, instead of being flat, is spherical, like the surface of the ocean viewed on the large scale; the geometry of figures traced on such a surface will then differ importantly from that of figures on a flat surface. On a spherical surface we can not, of course, draw a straight line in the usual meaning of that term; but we can draw one after Euclid's definition: the shortest distance between two points; and, as every navigator knows, this will be an arc of a great circle. There is a name used in general for such a shortest line traced on a curved surface of any kind: it is called a geodesic line. Its actual shape will, of course, depend on the way the surface is curved and the direction in which the line is drawn. On a cylinder, for instance, a geodesic may be a straight line, an arc of a circle or some intermediate form, according as it is drawn parallel, perpendicular or oblique to the axis of the cylinder.

On our spherical surface the three angles of a triangle (constructed of geodesics) will exceed 180° by an amount proportional to the area of the triangle. This is called the spherical excess. And upon such a surface two arcs of great circles will always intersect each other if sufficiently produced; that is to say, through a given point no geodesic (or "straight") line can be drawn parallel to (that is, not meeting) a given geodesic. A surface possessing these geometrical properties is called a surface of positive curvature.

On such a water-surface a floating particle, if set in motion, and free from the action of all forces, frictional, attractional or otherwise, would travel by the shortest, "straightest" path it could find, obeying Newton's first law of motion with the added condition of being confined to the spherical surface; that is to say, on a curved surface, the natural path of a body moving under the action of no force is a geodesic.

Surfaces of negative curvature may be constructed, on which the geometry is just the opposite of that on a surface of positive curvature; for on such a negatively curved surface the three angles of a triangle sum up to less than 180°, and through a given point more than one geodesic can be drawn parallel to (*i.e.*, never meeting) a given geodesic. Examples of such surfaces are the stem of a wine glass, a saddle, or a mountain pass. On such a surface the geodesic, from a Euclidean point of view, would be a curiously twisted line.

To sum up, we may say that a space is Euclidean if the geometry of figures drawn in it obeys the traditional postulates of the Euclidean geometry, and in particular that one which assumes that through a given point only one parallel can be drawn to a given straight line. If the figures drawn in a space do not conform to this postulate the space is said to be non-Euclidean.

Returning now to our flat surface of water, let us render it non-Euclidean by curving it in still another fashion. By careful manipulation it is possible to lay upon the surface of the water a particle of a heavy body such as lead, or even gold, so that it will float. The only thing necessary is to avoid breaking through the surface. The particle then lies supported by the unbroken water surface bent into a cusp or depression. Here we have a surface, normally two dimensional, bent or depressed slightly in the direction of a third dimension in the vicinity of a particle of matter. If we examine the geometry of figures traced upon the curved portion of the water surface, we shall find it non-Euclidean, and of negative curvature. The geodesic of this part of the surface will be a curved line of some kind; but if continued well beyond the cusp in either direction the geodesic will soon be indistinguishable from an ordinary straight line, and the geometry of these distant portions of the surface will be Euclidean.

Suppose now a comparatively heavy particle thus floating and forming a rather deep and widely extended cusp. At a great distance, in a Euclidean region of the surface, suppose a much smaller and lighter particle, which hardly produces any cusp, moving freely along the surface in a direction that will carry it past the heavy particle at a short distance, well within the latter's cusp. The path of the moving particle, at first a straight line, will as it enters the

cusp gradually assume the curved or geodesic form proper to the space in which it finds itself. Assuming no attractive force to exist between the particles, the moving particle will pass on and out of the cusp, its path again becoming straight; but on account of the brief twist to which it was subjected in passing through the cusp the final straight portion of the path will not in general be a continuation of the first straight portion. The particle will have suffered a permanent deflection.

An observer watching the motion of the particle through what we may call Euclidean-Newtonian spectacles, which do not show him the curvature of the water surface, will say: "Yes, on passing the heavy particle the light particle seems to have suffered a force of attraction of some kind, and to have been deflected from its straight path." But let him replace these glasses by others of Einsteinian make, and he will say: "No, I see now that there was no force of attraction at all. It was purely the inertia of the moving particle combined with the peculiar curvature of the surface which it had to traverse that produced the change in its path."

So much for a two-dimensional surface curved in a third dimension. Einstein's equations describe an analogous phenomenon occurring in a space of four dimensions curved or cusped slightly around each particle of matter, in the direction of a fifth dimension. A ray of light coming from a star traverses for millions of miles a region of space remote from material bodies, and consequently "flat" or Euclidean. Through this region the path of the light ray is a straight line. But if it eventually passes close by the sun, whose great mass causes a considerable cusp or warp in space, rendering it non-Euclidean in the immediate vicinity, the straight line becomes twisted into the geodesic proper to a space of such a curvature; and when it again becomes straight it has been permanently deflected from its original course.

The concept of a fourth dimension has been laughed out of physics many times since Lobatchevsky's day, but it has always returned, and would seem now to be more firmly entrenched than ever.

"But what is all this?" says some one. "In your title, which inveigled me into reading thus far, you promised to confine yourself to common sense; and now what are you doing?"

The Einstein theory has been called many bad names; "repugnant to common sense" is one of the mildest of them. But we may submit in this connection that there is another theorem respecting gravitation, or at least center of gravity, which, though accepted as orthodox and unobjectionable, is, if taken literally, as unreal, as absurd, as repugnant to common sense as anything in Einstein.

In calculating static moments we are accustomed to assume that the entire mass of a body is concentrated in its center of gravity.

"Oh, but," you say, "this is only a mathematical fiction, a short cut. Bodies behave *as if* this was so. Every one understands it."

Well, why not be charitable enough to extend the same tolerance to Einstein? Why not say that bodies behave *as if* space were curved, and *as if* gravitation were nothing but inertia? Does not this supposition fit the facts more closely than anything that has ever been proposed before? Regard it, if you will, purely as a mathematical fiction, with no physical reality necessarily behind it. What is real? "What is truth?" Pontius Pilate was a philosopher.

This, I believe, is the common sense of the theory of relativity.

Not only *may* we regard the theory in this light, but, I think, we *must*. We have considered the theory so far in its most favorable aspect; we have allowed it to put its best foot forward. Yet there is more of the story to tell.

Fitting a theory to the facts of Nature is much like fitting an equation empirically to a natural curve. It is not difficult to do this for a short piece of the curve; sometimes several equations are equally satisfactory; but if we need an equation that will hold over a more extended range it is not always easy to obtain a close fit at all points. So it is with the curve of Nature. We desire to find an equation which will fit it over at least as much of its range as is concerned with gravitation. The Newtonian equation does this almost perfectly; but there is one little kink in the curve, caused by the planet Mercury, into which the Newtonian equation is too smooth to fit; and when we follow out the curve into regions until recently unknown we find the Newtonian equation begins to diverge widely. Throughout this whole range the Einstein equation follows perfectly the curve of Nature, fitting the little Mercury kink, and running closely in the newly discovered region of the relation between light and gravitation, where the Newtonian equation parts company completely.

But Nature's curve runs on indefinitely; how far will the Einstein equation follow it?

Perhaps it may not go much farther.

I have said that the Einstein theory undertook the always precarious task of prediction; and in one case (the gravitative deflection of light) it succeeded spectacularly. But the theory contains yet another prediction. It indicates that certain lines in the solar spectrum should be shifted slightly out of place. The amount of shift indicated is very small, and difficult to pick up with certainty in the presence of pressure-shifts, Döppler effect and other corrections. While no final verdict has been reached, there does appear

to be some evidence unfavorable to the theory;[3] and certain of Einstein's enthusiastic followers have raised the question as to whether this point is really a necessary consequence of the theory. Einstein himself maintains, however, that this point is as vital as any other, and that if the experimental verdict is finally against it the whole theory is discredited.

I think we may see in this utterance of Einstein how sanely he regards this child of his brain. Being a mathematician he naturally recognizes the empirical equation fitted to a curve as something totally different from the real equation, and bound to diverge from it if carried out far enough. "No amount of experimentation," Einstein is reported to have said, "can ever prove me right. A single experiment may at any time prove me wrong."

But where the theory of relativity shows most plainly its artificiality is not in that part of it dealing with gravitation, but in the older or special theory, as it is now called, published some ten years before the gravitational or general theory was announced, but rounded out and completed only after the latter publication. This part of the Einstein doctrine was inspired by the negative result of the Michaelson-Morley experiment and similar attempts to detect our absolute motion through the ether, and is founded upon the postulate that it is impossible by any experiment that may be devised to detect our absolute motion in space. Physically, this appears to be true for motion of translation; but rotational motion is a different matter. Were the earth enveloped in perpetual cloud we could still, by the Foucault pendulum experiment, or by the gyroscope, detect its rotation. For this argument the theory of relativity has an answer of a kind; but, as Eddington says, when we come to rotational motion the theory of relativity stops explaining phenomena and begins explaining them away.

The answer of the relativist in this case harks back to the Ptolemaic astronomy. Where we are accustomed to consider a rotating earth, accompanied by a field of centrifugal force, surrounded by a relatively stationary universe of stars, the relativist considers a stationary earth and a rotating celestial sphere! Quite a step backwards to the dark ages? Well, it might be if his equations did not show that a hollow rotating body will apparently exercise a very small force on a body within it. A pendulum vibrating within a massive, hollow, rotating cylinder will, according to the Einstein equations, be deflected in the sense of the rotation, dragged around slightly by the moving mass. And the equations even indicate something simulating centrifugal force in a stationary system inside a hollow rotating mass.

[3] Additional evidence favorable to the theory has recently been adduced by St. John, whose earlier experiments were unfavorable.

Mathematically, the theory thus has an answer; but this answer, though mathematically perfect, lacks one very important property which Eddington calls "convergence."

To produce this quasi-centrifugal effect, which is very small, an enormous rotating mass is required; and the greater the radius of the rotating hollow body, the greater the mass needed. If the observed centrifugal effect upon the earth's surface is due to the rotation of the celestial sphere and the sum total of the mass of the fixed stars therein contained, this mass must be enormous, far exceeding any reasonable estimate that can be entertained. Either the dark suns of the universe must enormously outnumber those that are visible, or we must ascribe the effect to still more distant, and consequently much greater masses. The farther off we place the reckoning, the more we have to pay. The universe, on this hypothesis, is like a pyramid standing on its apex. Here, I think, the theory of relativity shows plainly its nature: a hollow mathematical shell, with no real content; useful when it fits the facts, useless where it does not. In this connection I may quote a pithy characterization once made to me about a person by a mutual friend: "Do I know Mr. X? Oh, yes; he's all right as long as he's all right."

The extreme to which this relativist line of argument might carry us is shown by considering several bodies like the earth, A, B, C. . . . If these bodies are not more than a light-year or so apart, they may all be considered as practically at the center of the celestial sphere if any one of them is. Suppose body A exhibits centrifugal force and bodies B, C . . . do not; how are we to account for this? Simply and easily, if we suppose A to be revolving and all the others stationary; but not so simply if we suppose A stationary, and the celestial sphere in motion; for to avoid a consequent production of centrifugal forces on B, C . . . the relativist must assume them in rotation also. Startling as this explanation is, it is no new thing under the sun; for the first of all relativists accounted for the apparent motion of surrounding bodies by the simple and soul-satisfying explanation: "Everybody's drunk but me."

In this brief review of the theory of relativity we have endeavored to keep a common sense perspective; to recognize its strength and to point out its weakness. Before closing we must discuss several points which do not fall exactly in either category: we must defend the theory of relativity from certain attacks which are unjustified.

One point about which a great deal of controversy has centered is the statement that the theory of relativity shows that a material particle can not have a speed exceeding that of light. This state-

ment is not found in Einstein's original papers. It is referred to as an error by Cunningham and by Silberstein; it is not mentioned, except in a modified and unobjectionable form, by Eddington. In Einstein's latest official utterances (his Princeton lectures) this statement does not appear; but it is found in a footnote, possibly from another's hand. It occurs also in several other American writings.

That the inertia of a moving charged body approaches infinity as the speed approaches the speed of light was known before Einstein, as a consequence of the classical theory, and found experimental support in the evidence furnished by rapidly moving electrons. No antagonism was aroused by this doctrine, as the source of this increased inertia was evident in the work spent in the production of a moving electro-magnetic field.

An important theorem in the older or special theory of relativity is concerned with two systems, A and B, B being in motion relative to A, and both systems being in communication by light signals sent from A to B. Certain formulas result which break down, or furnish imaginary values, when the speed of B (relative to A) exceeds the speed of light. It seems likely that some one, having in mind the pre-Einstein doctrine of limiting speed mentioned above, and regarding Einstein's formulas with more enthusiasm than discrimination, concluded somewhat hastily that there was some connection between them. As a matter of fact, it is, or should be, at once evident that the breakdown of Einstein's formulas is due to nothing more transcendental than the fact that if B is moving with a speed greater than that of light, A's light signals can never overtake B at all.

The theory of relativity has been criticized for doing away with the ether without offering any substitute explanation for the mechanism of propagation of light, and, in particular, for maintaining a dense silence on the subject of interference. To this, I think, the relativist may fairly answer that the theory contemplates the propagation of light only in its larger aspect, in its motion along the "path of least action," a geodesic in curved space, and with the phenomena deducible from this hypothesis. As for doing away with the ether, this process had progressed so far before Einstein that it was not uncommon to define the ether simply as "the nominative of the verb to undulate." As a matter of fact, Einstein's space is not at all bad as a modern concept of the ether; for it might be equally well described as "the nominative case of the verb to be bent"; and if it can be bent, why may it not vibrate? Why may we not have ripples superposed on the larger, static curvatures of material origin, and traveling according to the usual laws of the propagation of disturbances in an elastic medium? On this view,

there is little to choose between the old and the new. Matter is a static strain, a permanent deformation in space, ether, or what you will; and it is only necessary to endow Einstein's conception of space with elasticity as well as deformability to have at hand a fine structure capable of accounting for the optical phenomena about which the theory of relativity is silent.

Another matter can not be passed here without mention, as it has led some to the unjust generalization that there is something about relativity which has a tendency to turn a previously sane head. For this, also, one of Einstein's disciples is responsible. It is a remarkable thing that one who is easily the most brilliant expounder of Einstein, and who has served the present writer as a Rosetta stone to the Einstein hieroglyphics, should be obsessed by the delusion that when a quantity becomes unity it loses its dimensions. The mathematical consequences of such a procedure can lead only, as Lodge justly remarks, to confusion.

Perhaps this review may lead some one to read, or attempt to read, Einstein. It must be said that he is almost unreadable, even to a physicist with something more than the average mathematical equipment of his order. As a commentary to be recommended in all respects, mathematical or non-mathematical, we may suggest Freundlich's little book entitled: "The Foundations of Einstein's Theory of Gravitation," translated by Brose. For the older, or special theory, Cunningham is a sane and simple writer. Eddington is brilliant and mentally stimulating in his non-mathematical moments; but his mathematical writings are not to be recommended to the beginner.

As a general theory of the Cosmos, the Einstein theory is suggestive of the Ptolemaic astronomy. The Ptolemaic theory was not to be despised in its day. It was no mean conception and explained perfectly every astronomical fact known at that time. But even if there had been no Copernicus, the Ptolemaic theory would have broken down with the advent of Foucault. And so it is with the Einstein theory. For sheer complexity it out-Ptolemizes Ptolemy; and many of us, doubtless, recall with sympathy that profane but practical King Alphonso, who, apropos of the Ptolemaic system, regretted that he had not been present at the Creation; he could have suggested a better plan. Not that any one at present has a better theory to suggest than that of Einstein; but such a thing may and doubtless will come to pass when the hour and the man arrive. Newton cut so closely that over two centuries elapsed before an Einstein could better his formula; and how long it will be before the next corrective term is added to the empirical equation for the great curve of Nature is a matter at present on the knees of the gods.

RECENT DEVELOPMENTS IN IMMIGRATION

By Professor ROBERT DE C. WARD
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The Labor Shortage

American industry has been suffering from a widespread shortage of labor. Of that there is no doubt. The situation has, however, been exaggerated and the causes which led to it have been misunderstood. It is a highly complex problem, and many factors are concerned in it. This labor shortage has been very generally but wrongly attributed chiefly to the three per cent. quota immigration law. People forget that labor shortages occurred before the days of restricted immigration, and that only during times of business depression has there been an abundant labor supply. When they agitate for a larger immigration from southern and eastern Europe they forget that the sweat-shop workers and peddlers who nowadays make up a considerable part of that immigration are not the sort of workers whom we need; and that ignorant pick-and-shovel men are not fitted to operate the agricultural machinery on a modern American farm. The effects of the labor shortage are also greatly exaggerated. The cry for more harvest hands in the wheat fields of the West is perennial, yet the dire predictions that the wheat crop will be ruined because of the shortage of men to harvest it have never come true. Again, in spite of all that Judge Gary and others have said about the difficulty of introducing the eight-hour day in the steel industry because of the inadequate labor supply, that most desirable change is nevertheless being accomplished. The "interests" which are calling for more labor really want cheaper labor. They are trying to prevent further restrictive legislation by carrying on a campaign against the present law.

It is a mistaken idea that the three per cent. law has reduced immigration to negligible proportions. The regular legal quotas permit an annual inflow of over 350,000. In addition, aliens who have lived five years in British North America, Mexico, Central America, the West Indies and South America, as well as a very considerable number of "excepted" classes, can come in without limit as to numbers. Under this provision, many thousands of immigrants have come from Canada and from Mexico. In the fiscal year ending June 30, 1923, over 500,000 aliens were admitted according to the official count, but tens of thousands of others were smuggled in or, having entered American ports as seamen, left their ships and became illegal residents here.

"A crude labor shortage is here to stay," as an editorial writer in one of our most influential industrial papers recently said, adding, "it would be most alarming if the prospects were otherwise." Our people as a whole are clearly determined that a flood of "cheap" alien labor shall never again enter our ports. They believe that the prosperity of the United States does not depend upon any such importation. They are convinced that this country is better off when every one is steadily employed at good wages than when hundreds of thousands of unskilled and ignorant foreigners are being landed every year, unsettling the labor market and greatly aggravating the conditions of unemployment in periods of business depression. Much of our labor is not effectively employed. In most industries the labor turnover is far too large. There are too many peaks and depressions of employment. Hundreds and thousands of men and women are at work only part of the time. Further, we have not begun to use labor-saving machinery as fully as we should. When men become too expensive, or when there are too few of them, labor-saving machinery takes their place. Countless jobs are to-day done by machinery which a few months ago were being done by ignorant foreigners. This is true of the farm as well as of the factory and the mine. It is infinitely better for the country that it should be so. Our future labor supply can be mainly recruited out of the loins of the people who are already here, and augmented by a limited inflow of selected alien immigrants. In the minds of competent authorities, there is no doubt that immigration, by reducing the native American birth rate, has not increased the population of the United States but has changed its character. Our population would probably be fully as large as it now is had there been no immigration at all since the foundation of the Republic. For the United States it is a clean-cut decision between developing our own labor supply here or perpetuating in our midst a definite coolie class, steadily recruited through the immigration of unskilled alien laborers. The patriotic course for our large employers to pursue is to stop complaining about the "need of labor"; to set themselves to work to reduce their labor turnover; to introduce labor-saving machinery; to improve working conditions; to face the facts of the situation. An intelligent American, with an American-made machine, can do the work of a dozen ignorant foreigners. This is good sense. It is good business. It is a sound American policy. And it will greatly decrease the distress of unemployment when business conditions are bad. Mr. Edward A. Filene, of Boston, a large manufacturer and employer, has put the economic situation clearly as follows: "Employers do not need an increased labor supply, since increased use of labor-saving machinery and elimination of waste in production and distribution

will for many years reduce costs more rapidly than wages increase and so prevent undue domination by labor."[1]

The Monthly "Race" to Quarantine

With the beginning of the new fiscal year (June 30, 1923) and the opening of the new quotas, there again occurred "races" to quarantine of immigrant-carrying steamships. "Sob-stuff" stories of the hardships of aliens who had to be debarred because they exceeded the regular monthly quotas were prominently displayed on the front pages of the daily papers. What are the real facts in this situation?

Under the law, 20 per cent. of the total annual quota of any nationality may be admitted in any one month. Because of this provision, we have a tremendous rush in the first few days of the first five months of the fiscal year, with the resulting congestion, hardships, and, unfortunately, very hurried and inadequate medical and general inspection. The difficulty here is far less a defect in our law than a failure on the part of the steamship companies to take proper precautions to obey the law. Under the law, express provision is made for the issue, by the Immigration Service, of frequent and regular statements, showing just how many aliens of each nationality are still admissible. Every facility is given to the steamship companies to ascertain the exact status of the quotas at any time. But the majority of these companies—there have fortunately always been a few exceptions—have acted on the assumption that they have vested rights in the United States as a dumping ground for their human cargoes. They prefer to take the chance. They are primarily interested in getting the steerage passage money. The result is that many perfectly honest aliens are brought over, expecting to land, and then have to be deported. The trouble is not with the law. It is with the steamship companies, which, it may be added, have a good many reasons for wishing to make every restrictive immigration law appear inhumane, unjust and non-workable. The Commissioner of Immigration at New York clearly laid the blame where it belongs when he said of the steamship companies that they are "dealing in dividends of human beings to satisfy their own greed." This is the whole situation in a nutshell.

The Geddes Report on Ellis Island

A very unnecessary flurry was caused by Ambassador Geddes's report on conditions at Ellis Island. A careful reading of that report fails to show that there are any very serious evils at our principal immigration station which, under the conditions of congestion

[1] *Sat. Eve. Post,* July 28, 1923.

during the early days of the first five months of the fiscal year, can be wholly overcome. Immigration officials in Washington and New York sufficiently answered the ambassador's criticisms. The United States is doing its utmost to keep the island clean and sanitary, and to treat arriving immigrants humanely. Any one who thinks this an easy task should spend several days at Ellis Island during the time of congestion. The trouble is chiefly with the aliens themselves, many of whom have not the remotest conception of cleanliness or of common decency, as Anglo-Saxons understand those terms. The keynote of Ambassador Geddes's report is contained in the following concluding sentence: "What Ellis Island needs, in my judgment, is to be relieved of the presence of about one half of the people who are poured into it." Americans seeking an improvement in the conditions of immigration may well take those words to heart.

What the Percentage Immigration Law has Accomplished

The three per cent. law is not perfect, but it has on the whole worked successfully and has fully justified its enactment. Without it, our immigration during the past two years would surely have amounted to between two and three millions a year, and 80 per cent. or more would have come from southern and eastern Europe. For a good many years before the war, aliens from southern and eastern Europe very largely outnumbered those from northern and western Europe. Under the law, the numbers are about equalized. There is absolutely no doubt that this limitation upon the numbers of southeastern European immigrants has greatly stimulated immigration from northwestern Europe. As long as immigration from southeastern Europe was unlimited, people from northwestern Europe did not come here in large numbers for the reason that they did not want to compete with hordes of ignorant and unskilled aliens who are contented with low wages, low standards of living and frequently intolerable working conditions. The situation has now completely changed. Since the United States has placed a definite limit to the numbers who can come from southeastern Europe, immigration from northwestern Europe has taken a distinct spurt, and there has been a steady increase in the numbers of the better-class northern and western Europeans who are coming here. The quota law is accomplishing just what its advocates predicted, and there are few outside the ranks of the hyphenates who do not realize that this is a very distinct gain for the country.

Not only so. The number of native-born workers in many of the better-paid occupations in this country is increasing because of the decreased competition with newly-arrived aliens of the lower grades. This trek of native-born into jobs on which aliens have

been employed proves the soundness of the position long maintained by unprejudiced students of our immigration problems. There are no jobs which "native labor" will not do, provided the pay is sufficient to support a self-respecting American workman according to American standards of living. As the late General Francis A. Walker used to say, there is no job too "mean" for a self-respecting American to do. It is the low-grade man who makes the mean job. Until ignorant and unskilled foreigners came to the United States, nothing was said about "mean jobs which native Americans refuse to do." It is chiefly because they do not wish to associate and compete with the lower grades of newly-arrived aliens that young Americans who graduate from our public schools disdain manual labor which, because it is so largely performed by aliens, is considered degrading. There is a very vicious circle here. The greater the inflow of "cheap" immigrants, the less will young Americans want to compete with them in manual occupations, and then the more immigration will be needed to do these jobs. The continued importation of great hordes of ignorant aliens would still further degrade manual occupations, and still further interfere with the development of a high class of native workmen. Further, now that a vast amount of hard manual labor can be done by machinery, there is far less need than there used to be for a huge supply of crude labor. The quota law, which has reduced the numbers of common hand laborers from southeastern Europe, has brought us an increasing number of intelligent skilled northern Europeans, who already know how to manage machines, or who can easily be taught the use of American labor-saving machinery.

Suggestions for New Legislation

Americans have been doing a good deal of serious thinking on the question of their future immigration policy. It is a difficult problem, but public opinion seems to be crystallizing around these three points: (1) Never again is there to be an unlimited inflow of cheap alien labor; (2) a numerical limitation of immigration is here to stay; (3) there must be a careful selection of our immigrants within the fixed limits. To accomplish these ends we should have (1) percentage limitation; (2) based on the census of 1890, and (3) some form of overseas inspection. The conviction that the census of 1890 should be used as the basis of any percentage law has been growing rapidly all over the country. Since there were fewer southeastern Europeans here in 1890 than in 1910, a percentage provision based on the former census would decidedly cut down the numbers of immigrants from that area. The great majority of our people are opposed to the continued inflow of low-grade unskilled foreign labor and are in favor of the immigration of skilled labor. This provision would accomplish both objects. It would change the

character of immigration, and hence of our future population, by bringing about a preponderance of immigration of the stock which originally settled this country and which still makes up the bulk of our population but can not continue to do so without such legislation. It can not be denied that on the whole immigrants from northwestern Europe furnish us the best material for American citizenship and for the future upbuilding of the American race; that they have higher living standards than the bulk of southeastern Europeans; are more homogeneous; of a higher grade of intelligence; better educated; more skilled; better able to understand, appreciate and support our form of government. A percentage limitation based on the 1890 census offers a simple, practical solution of many of our immigration problems, and is sound American policy, based on historical facts. Unprejudiced observers of recent immigration are agreed that the bulk of the aliens who have been coming here from the countries of northern and western Europe are good types, able-bodied, physically fit, independent, paying their own passages, many of them farmers and skilled workmen, and avoiding the congested districts of a few large cities. Southern and eastern Europe, on the other hand, have been sending large numbers of peddlers, sweat-shop workers, fruit-stand keepers, bootblacks and the like, mostly non-essential members of the community, and flocking to the centers of densest population.

The country at large has been greatly impressed by the results of the army intelligence tests made during the war, which have been thoroughly analyzed by Lieutenant-Colonel R. M. Yerkes, Dr. C. C. Brigham and others. The generally higher intelligence of our recent immigrants from northern and western Europe is definitely established, as is the fact that the immigrants who have been coming during the past few decades, mostly southern and eastern Europeans, have been steadily deteriorating in intelligence. The men who have analyzed the statistics have made careful tests of the tests themselves, and are convinced "that the responses to the tests reveal only innate intelligence and not acquired information and education." This answers the argument that the drafted men who were natives of northwestern European countries, most of whom had been in the United States for some time, were better able to profit by the benefits of American environment and educational facilities, and hence were at an advantage as compared with the more recently arrived recruits from southeastern Europe.

There are many people to whom intelligence tests do not appeal, or who more or less distrust them. To such the "pocket-book argument" comes a good deal closer. Dr. H. H. Laughlin has recently made a very thorough investigation of the "socially inadequate" groups in 445 state institutions. His report should be carefully

studied by every American. Of the institutional population thus studied, 44 per cent. was either of foreign birth or had one or both parents foreign-born. The states whose public institutions were examined are devoting on an average nearly eight per cent. of their total expenditures to the care and support of the inmates of foreign birth or parentage. In many states the expense is much greater. The State of New York in a recent year was spending over $4,000,000 for the care of insane aliens in civil hospitals. It should be remembered that these figures take no account of the foreign socially inadequate in private institutions, or supported by private charity outside of institutions. Dr. Laughlin's studies bring out another very striking and important fact, *viz.*, that immigrants from northwestern Europe contribute far less in proportion to our alien socially inadequate institutional population than do those from southeastern Europe. A percentage limitation based on the census of 1890 would therefore not only reduce (1) the inflow of unskilled "cheap" labor, but would also greatly reduce (2) the number of immigrants of the lower grades of intelligence and (3) of immigrants who are making excessive contribution to our feeble-minded, insane, criminal and other socially inadequate classes. Such a provision is the simplest, most logical and most effective means readily at hand for accomplishing all three of these very necessary things.

American public opinion is also firmly convinced of the need of (1) a far more effective system of inspection at our own ports, and of (2) some sort of preliminary selection overseas. The former requires larger appropriations and more and better paid inspectors, both general and medical. The latter has for years been advocated as necessary and humane—a benefit to the United States and a means of preventing unnecessary hardship to the alien. There have always been many and serious difficulties in the way of our establishing a complete and thorough system of foreign inspection: the expense; the need of a very large number of medical and other officials; the great opportunities for graft and corruption if natives of other countries are employed abroad as clerks, interpreters, and the like; the objections of certain foreign governments to our making a selection of prospective immigrants on their own territory. In spite of these obstacles, it has seemed that by means of a little skilled diplomacy it might be possible to bring about at least some sort of preliminary selection abroad. For example, definite assurance on the part of a foreign government that all intending immigrants had been examined and found eligible under our immigration laws, and that they belonged to the classes of aliens desired by us, might make our own inspection overseas unnecessary (we must always have inspection at our ports of landing in any case), and

would satisfy any question of international relations. During the past summer Secretary of Labor Davis has been abroad studying the possibilities of a plan for having prospective immigrants examined in their own countries, and according to press despatches he has in preparation a new immigration bill embodying the features of examination abroad and registration of all aliens entering this country. If Secretary Davis has been able to bring about any such working plan with foreign governments he will have made one of the most important possible contributions towards the settlement of our immigration problem. What Secretary Davis is seeking is "not a foreign policy, dictated by foreign steamship companies, but an American policy, formulated by and in the interests of the United States." With that point of view all Americans will surely agree.

Scientific Studies of Immigration

Our immigration policy in the past has been too much a matter of temporary economic or political expediency. One of the most encouraging recent developments is the rapidly growing conviction on the part of our people that, as Dr. H. H. Laughlin has admirably stated it, "immigration is a long-time investment in family stocks rather than a short-time investment in productive labor." Many of the leading scientific men in the United States are now making a study of the problem in order to ascertain, by careful scientific methods, the facts which may be useful in guiding future legislative action. These men have no political or sociological axes to grind, and are wholly unprejudiced. At least two organized scientific bodies are now at work on the matter. The National Research Council has appointed a committee of experts in anthropology and psychology, as well as in vital statistics, heredity and the influences of environment. This committee is already at work. Further, the newly organized Eugenics Society of the United States has decided to begin its labors with chief emphasis on three subjects, one of which is "working out and enacting a selective immigration law." There is no doubt whatever that the results of these scientific studies will be of the utmost importance in our future immigration legislation. Experts have already told us that had mental tests been in operation, and had the "inferior" and "very inferior" immigrants been refused admission to the United States, over 6,000,000 aliens now living in this country, free to vote, and to become the fathers and mothers of future Americans, would never have been admitted. Now that the facts are known, the American people are not going to stand for any such degradation of American citizenship, and any such wrecking of the future American race.

THE BLACK WIDOW: ITS LIFE HISTORY AND THE EFFECTS OF THE POISON

By W. J. BAERG
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THE Black Widow, *Latrodectus mactans,* and the tarantula are the two species of spiders of Boreal America that many arachnologists and medical entomologists regard as dangerously poisonous. The Black Widow is a small black spider; its abdomen is nearly globular, shiny black above and with a dark red hour glass figure below. The cephalothorax (head and thorax) is very small in comparison with the abdomen. The female spider is about one half inch in length. The male is about half the size of the female. It has a red stripe along the middle of the back, and may have a series of stripes on the sides of the abdomen.

The Black Widow is frequently mentioned in scientific literature. The genus seems to be cosmopolitan, and all the known species apparently enjoy a reputation similar to that of our *L. mactans.* Recently there have been a number of shorter articles in *Science* and other journals reporting cases of poisoning attributed to the Black Widow. These cases are quite like the ones cited in text-books of medical entomology; they are based on circumstantial evidence, and the reported effects vary all the way from a slight indisposition to death.

In America the Black Widow is not so well known to the general public as it is in some other countries. In Southern Russia, where *L. erebus* occurs, it is greatly feared by the natives. When this spider seems at all common, children and older persons are employed to search the fields and meadows and kill the dreaded spiders. At such times the men and women working in the field are advised to be provided with a piece of a raw onion, which, in case of a spider bite, is rubbed over the bitten place and is said to prevent serious consequences.

The species of *Latrodectus* occurring in Madagascar, New Zealand and elsewhere are likewise generally known to the natives and universally feared.

With reference to occurrence in Southern Russia, I am told that it is commonly believed that the Black Widow is present in considerable numbers only during dry seasons. This is possibly due to the fact that during such times the spiders may be forced to search for water, and on their wanderings they are more commonly seen.

In the Ozark region of Arkansas the Black Widow may be commonly found under stones. During normal seasons, it may be anywhere under stones that are not often disturbed. During a dry season these spiders seek shelter under stones in a dry creek bed or near a stream. At such a time they are also commonly found in the housing of water meters and probably also in basements of houses. Although they are very common in this region, they are here apparently not known as being more dangerous than other spiders. Many of the physicians know the Black Widow and have reported to me cases of poisoning presumably caused by this spider.

Life History and Habits. As already indicated, the Black Widow is most commonly found under stones. At about the middle of June, the females may be found, sometimes three or four under one stone, with their egg sacs or cocoons. Whether the females actually become sociable at this time, so as to seek each other's company or whether they merely exhibit such tolerance towards each other, in case they meet, is not settled. McCook believes that the latter is true with many spiders. I am inclined to think that the Black Widows actually become sociable in a degree at the time of egg laying. I found three females with three egg sacs under one stone, and another female with one egg sac under another stone near by. A careful search of several acres of ground in the vicinity failed to bring any additional spiders.

In this latitude the female constructs, in one season, as many as four cocoons; at the rate of about one every two weeks. Each cocoon holds about 300 eggs. The young spiderlings leave the cocoon about ten days after the eggs have been laid. In nature I have not observed any young; but I have reared them in the laboratory, placing from four to six cocoons in each of a number of quart jars. The young spiders feed on their brothers and sisters, even if flies and young grasshoppers are provided. Whether or not the same is true in nature, I can not say definitely; but I rather believe that it is.

When reared as just described, the females attain full growth in about two months. The males develop more slowly, and they are rather difficult to rear. In a jar where about 1,200 to 1,500 young spiderlings hatched, there were left, after five weeks, one nearly full-grown female and one half-grown male. In another jar having about the same number of young spiders, four females attained about half of their growth. Later, only one of these survived.

In nature the males are apparently very scarce during midsummer, while early in fall the young males, two thirds to full grown, may be found as commonly as the females. Apparently, most of the old females die at the end of the summer or during fall,

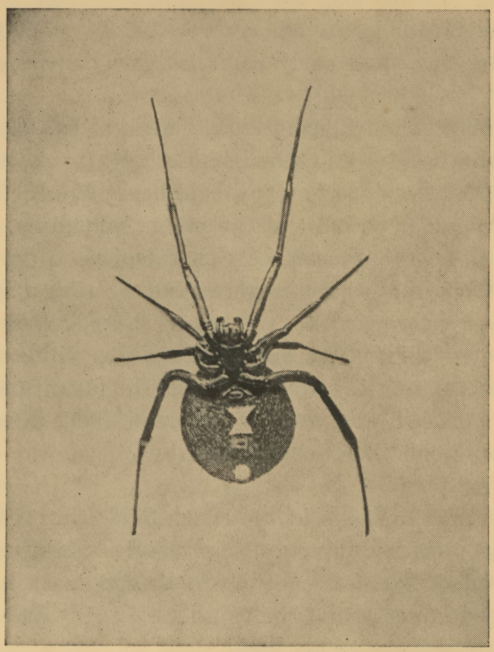

FIG. 1. Ventral aspect of *Latrodectus mactans*, female. Magnified three times.

FIG. 2. *Latrodectus mactans*, male. Magnified four and a half times.

although some of them may live through the winter, if I may judge by observations made in the laboratory. Of three females that were taken in June, two died early in fall. The third lived till January 10.

An informant from Southern Russia says that *L. erebus* is not shy and frightened by any disturbance, as are practically all the spiders. In the behavior of our own species, there is all the timidity and shyness common to most of the other Arachnida.

The Effect of the Poison. Arachnologists apparently do not regard the Black Widow as dangerous as the tarantula. Professor Comstock says in regard to the genus Latrodectus: "They are feared wherever they occur and it is quite possible that they are more venomous than other spiders." Of the tarantula, although he knows of no authenticated case of a person being bitten by one, he says, "I should not like to be bitten by one of the larger tarantulas."

James H. Emerton says of the Black Widow: "It is everywhere feared as poisonous and dangerous; probably on account of its large size and conspicuous colors, as there is no good reason for considering it more poisonous than other spiders." Mr. Emerton does not mention the tarantula in his book.

Henry C. McCook says of the Black Widow: "It must be confessed that the experiments of naturalists, as well as their observations, are unfavorable to the popular belief in the dangerous character of the spider's stroke, except in the case of the very large species, such as our American tarantula. Tarantulas with such large fangs and supply of poison are regarded as dangerous and should be handled with great care."

Mr. M. Lucas, an eminent arachnologist, states that he has been bitten repeatedly by the New Zealand species of *Latrodectus* and has not observed any ill effects.

Medical entomologists are agreed on the dangerous character of the Black Widow. Presumably this is because they have accepted the circumstantial evidence given by medical practitioners, conflicting as it is.

There is, so far as I know, not one well-authenticated record giving reliable information on the effects of the bite of the Black Widow. In all recorded cases, the identification of the spider is based on information given by the patient.

Dr. Rudolph Kobert attempted some tests with the bite of the European species of *Latrodectus,* but was unable to induce the spiders to bite the animals intended for experimentation. He then proceeded to make extracts of the cephalothorax of dried specimens in distilled water or physiological salt solution. Three cubic centi-

meters of the extract, containing 4.39 mg. of the organic material, were injected into a cat of average size. Complete paralysis developed in a short time and in twenty-eight minutes the cat was dead. The extract was injected also into rats, dogs, squirrels, sparrows, etc., and in all cases caused paralysis, followed by death.

Significant as these results are they do not give any information in regard to the effects of the bite. Neither are they entirely reliable in regard to the nature of the poison. An extract prepared from dried specimens, treated with salt solution, exposed to various temperatures, etc., can not be regarded as identical with the poison poured out through the fangs.

Dr. Marx made a similar study of the poison of *Latrodectus mactans*. He prepared an extract of the poison, injected it into guinea pigs and rabbits, but was unable to observe any definite symptoms.

Since there are but two spiders in Boreal America that are by medical entomologists and others regarded as dangerous, and since I had some time ago been able to satisfy my curiosity in regard to the poisonous nature of the tarantula,[1] I decided to make some tests with the other poisonous spider, the Black Widow.

The opportunity for these tests came last summer, late in June, when I found four full-grown females with their cocoons. By feeding them each a nymph of a meadow grasshopper once in five to six days, they were easily kept in an apparently normal condition.

The Effect of the Poison on Rats. For preliminary tests, white rats about four weeks old were used. The difficulty that several investigators have met, when trying to induce the spiders to bite, was overcome by feeding the spiders about forty-eight hours before the tests were to be made. Although, by observing this rule, all our attempts to induce the spiders to bite met with success, yet it seems very doubtful that this is the real or only reason for the results. By making a considerable number of tests one obviously acquires some little ability in holding the spiders properly, and this is perhaps more important in getting the desired response from the spiders than is the particular day of feeding.

The rats were prepared for the test by clipping off the hairs on the inside of the left hind leg. Two rats and two spiders were used in the first test. The spiders bit well and the fangs were allowed to remain inserted for several seconds.

In a short time both rats presented distinct symptoms of illness. They humped up, turning the head underneath till the face rested on the floor of the cage; from time to time they would jerk forwards as if in convulsions. The eyes were usually closed and the rats

[1] This Journal, May, 1922.

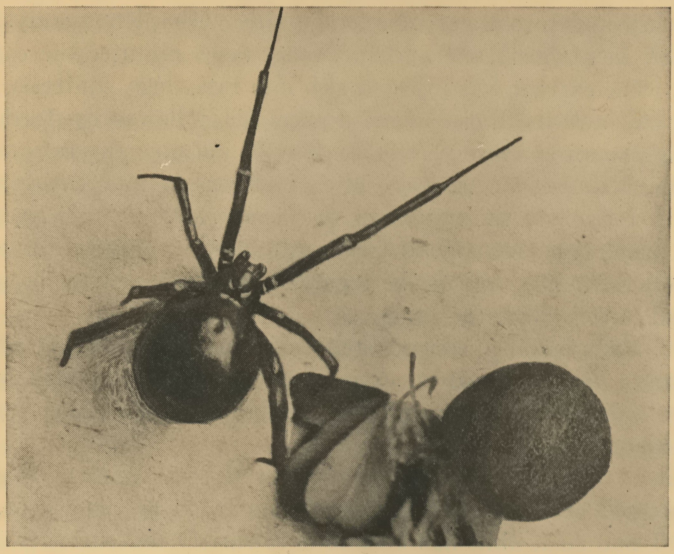

FIG. 3. Black Widow and cocoon. Magnified two times.

were not easily aroused. When walking they were very unsteady and stumbled frequently. These effects lasted from six to ten hours, when the rats rapidly recovered and behaved in an entirely normal manner. To confirm these observations the test was repeated, applying the same spiders to the same rats. The symptoms were very similar to those following the first test, but markedly milder.

Since these effects of the bite were relatively insignificant, it seemed desirable to compare them with the effects of the bite of a supposedly harmless spider. For this, I used a funnel web weaver, *Agalena naevia,* which is very common in this region. The funnel web weaver is admirably adapted for such tests. It is easily held and it bites as soon as its fangs come near enough anything they can penetrate.

Two young white rats were used for this test. For about thirty minutes following the bite, they appeared slightly affected; they sat somewhat humped up with eyes partly closed; then they proceeded to walk around, using the wounded leg freely, and otherwise behaved in an entirely normal manner.

The contrast between these symptoms and those following the bite of the Black Widow is very apparent. It is obvious that if the funnel web weaver injected any poison, which it probably did, this is quite innocuous. A question that has been raised by various workers is whether the Black Widow has relatively large poison glands or not. Dr. Marx reports that the glands of *L. mactans* are

relatively small. Bordas describes the poison glands of the European species, *L. guttatus*, as much larger than those of other spiders. Riley and Johannsen are convinced that the same is true of our American species of *Latrodectus*. It seems unfortunate that the names of "the other spiders" are not given.

The following measurements of the glands of the Black Widow and of those of the funnel web weaver, in connection with the accompanying figures, may help to clear up this question. The glands of *Latrodectus* vary greatly in size, especially in length. The longest glands found in dissecting six specimens measured 3.5 mm; the shortest 1.75 mm. (These two were used for the illustrations

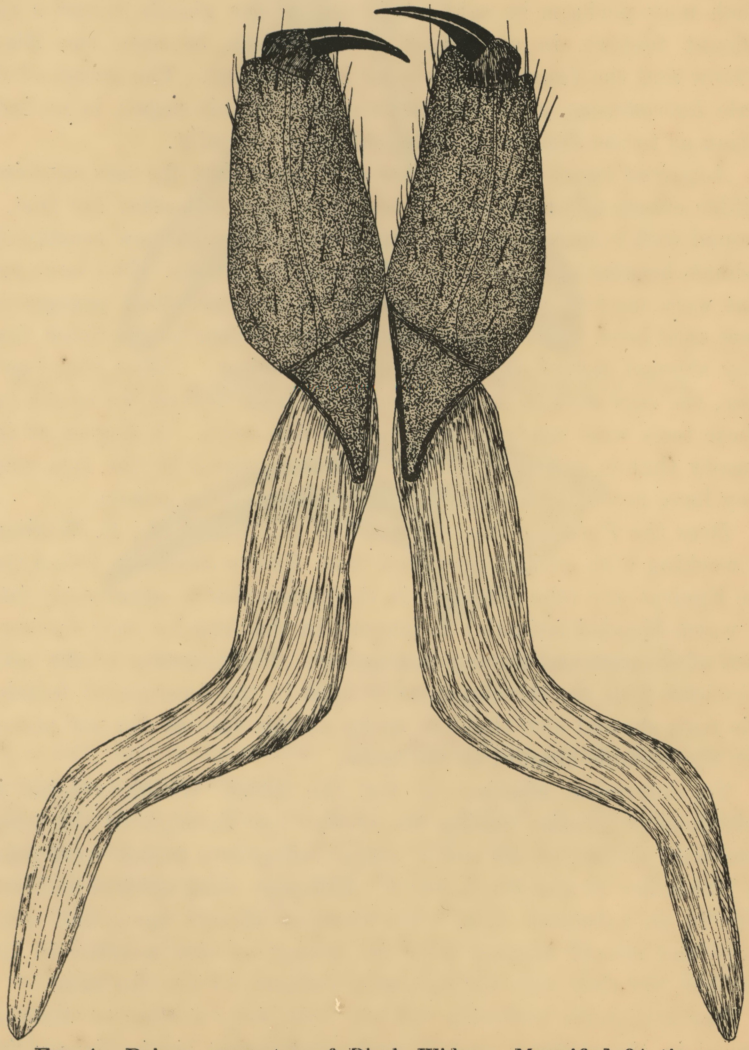

FIG. 4. Poison apparatus of Black Widow. Magnified 34 times.

of Figs. 4 and 5.) An average length is between 2 and 2.5 mm. The average width of the glands,—and this does not vary appreciably,—is .37 mm to .50 mm.

The glands of the funnel web weaver, from a study of a half a dozen specimens, were found to measure between 2.75 mm to 4.25 mm. in length, and 1.0 mm at the greatest width.

The glands of the male *Latrodectus* were studied in but one specimen. As the figure (8) shows, they resemble essentially those of the female. They measured .99 mm in length and .17 mm at the greatest width.

Even from this restricted study of the size of the glands, thus much may perhaps be said. The size of the glands is not a significant feature, in so far as a comparison between the Black Widow and the funnel web weaver is concerned. The gland of the male *Latrodectus,* as will be shown later in this paper, is no indication as to the dangerous or harmless nature of it.

Acquired Immunity. In view of the fact that the rats exhibited milder effects after the second test than they did after the first, it seemed well to make additional tests and determine how readily the animals became immune to the effects of the poison. The same rats that were used in the tests described in the preceding paragraphs were used here. When these rats had been bitten for the third time, they showed rather slight effects of poisoning. After the fourth time, the rats showed no other response than licking the bitten leg. These tests were made at intervals of one week. A degree of immunity that is well-nigh perfect is thus acquired by the rats when they have received three rather large doses of the poison.

Does the Poison persist throughout the Year? L. E. Walbum, in working with extract prepared from *Epeira diadema,* found that the Epeiratoxin (the principle in the poison that is apparently fatal to warm-blooded animals) is present in the females only during a part of August and during September. The presence of the toxin coincided with the development of eggs in the fecundated females. His tests showed also that the males of this species did not possess any appreciable amount of the toxin.

To determine whether or not the Black Widow retains its poisonous properties during the winter (or throughout the year) tests with an old female and a young full-grown female were made on November 26 and December 3. Although these spiders had been kept in an unheated room with windows always open, and seemingly had ceased feeding with the advent of cool weather in late October, yet they were rather easily induced to bite the rats.

The symptoms following the bite were very similar to those observed in the summer and showed clearly that the spiders retain

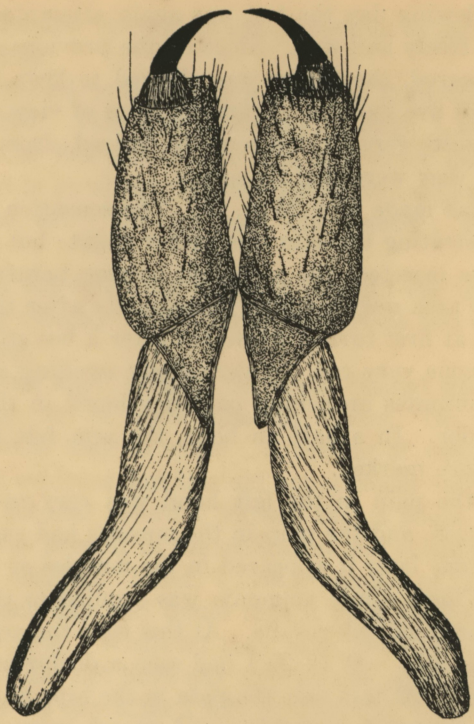

FIG. 5. Poison apparatus of Black Widow. Magnified 34 times.

FIG. 6. Fang of Black Widow, showing poison duct and teeth. Magnified 132 times.

their poison during the winter. The effect of the poison is the same in winter as it is in summer.

The Effect of the Bite on Man. On July 9, at the time when the second test was made on the two white rats, I decided to use a third spider on myself. The first attempt to induce it to bite practically failed. After much coaxing it finally made a very feeble effort and just pierced the skin of the inside of the third finger. The sensation produced by the fangs piercing the skin was barely noticeable. Later this spot was at times covered with profuse perspiration. No other significant symptoms were observed.

On the following day the test was again attempted. This time the spider bit freely and well. Since on the previous day no symptoms had appeared, the spider was allowed to keep the fangs inserted for about five seconds. From the point of view of the experimenter, the results were all that could be desired; from the subject's point of view, they were slightly severe.

The test was made at 8:25 A. M. The sensation produced by the fangs penetrating the skin was rather slight; but gradually, as the poison was injected, the sensation became painful, sharp and piercing. The area near the bite, immediately after the poison had been injected, at first turned white (as after a bee sting), but in a short time became very red. A very slight swelling appeared. In about fifteen minutes an aching pain developed in the tendons of the left shoulder. In a half an hour, the arm felt lame and the aching was more marked.

By 10:25 the pain in the left hand was very severe, a sharp burning sensation, and the pain in the muscles had extended to the chest. Some time later it appeared in the muscles of the hips. At eleven o'clock some dilute ammonia was applied to the left hand; but failed to produce any results. At this time the aching pain extended into the legs. At 12:20 I had seen a doctor and on his advice went to bed. At this time the pain in the hips was very severe, the chest felt cramped; breathing and speech were rather forced and irregular.

In view of the rapidly developing symptoms, it seemed best to go to the hospital. This I did at 5:30 in the evening. A hot bath that I took soon after coming to the hospital gave very appreciable results. The diaphragm was entirely relieved, and the aching pain, now felt in almost all the muscles of the body, was temporarily lessened. Unfortunately, a dressing soaked with a solution of $KMNO_4$, placed on the left hand by my physician, prevented me from holding this hand in the hot water.

During the night a desperate attempt was made to draw some of the poison from out of my hand. The $KMNO_4$ solution was renewed frequently and an electric oven, as hot as I could bear, was placed over my hand. This was left on for an hour or two, and then kept off an hour. The effort was all in vain, and incidentally caused much pain. At four A. M. I rebelled and it was discontinued. Obviously, I did not sleep at all; in fact, I did not lie still for much longer than thirty seconds at a time. Rolling about in bed seemed to ease the pain a bit.

In the morning after a hot bath, at which the left hand got a generous share, all pain was considerably relieved; in fact for a half an hour or so, I felt scarcely any pain. On the evening of this

day, I made the first attempt to eat, partaking of some oyster soup with much relish.

Another hot bath in the evening made me think that I had practically recovered. This was a mistake; though I slept for short periods, I was so delirious that as soon as I would doze I would be frantically and in an utterly aimless fashion working with—spiders. Truly a state of: "Die ich rief, die Geister; Werd'ich nun nicht los."

A hot bath the following morning brought the usual improvement. During the day I slept for short periods and spent most of the day reading.[2]

The following night brought the much desired sleep; there was some dreaming, but of quite innocent affairs. On the next day (July 13) I went back to work. A feeling of wretchedness was more or less in evidence, but this did not seriously interfere.

From the hospital record I learned that a slight fever, one to two degrees, was present in the afternoon and evening of the days I spent in the hospital. Later, I took a number of readings of my temperature each day and found that it kept fluctuating from 96 or 97 to 99 or 99½. Whatever may have caused this variation in temperature, it did not have any appreciable effect on my general condition. On the day after I left the hospital, I was again in the best of health, with a good appetite and usual vigor.

The experience had some unpleasant features in it; yet it had also its attractive features. The symptoms were all new to me, and each change presented a surprise. The unpleasant features were many times compensated for by the fact that I had satisfied my curiosity regarding *the other* of the two poisonous spiders of America.

The Poison of the Male Spiders. The question as to whether the male of *Latrodectus mactans* (Black Widower?) is able to inflict injuries similar to those attributed to the female has apparently not received any consideration. Walbum, as already noted above, found that the males of *Epeira diadema* did not possess any appreciable amount of the toxin.

The glands of the male, as may be inferred from the illustration and the measurements given on a preceding page, are, in proportion to the size of the male, about as large as are those of the female.

[2] In selecting the reading matter for this trip to the hospital, I had used too little care. It was Cytherea, by Hergesheimer. While I do not wish to invade here the field of literary criticism, yet the reading formed a part of this experiment, and the effect should be given. It was nearly as unpleasant as the effects of the spider poison.

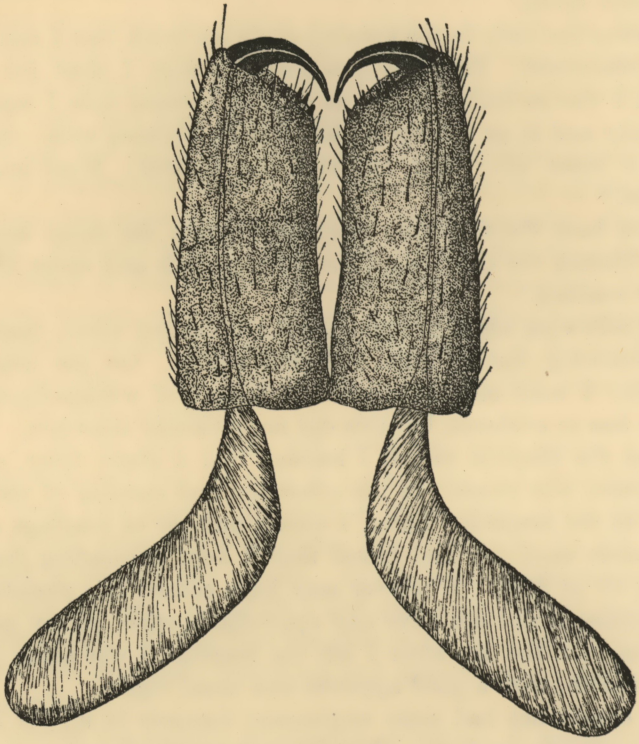

FIG. 7. Poison apparatus of a Funnel Web Weaver. Magnified 17 times.

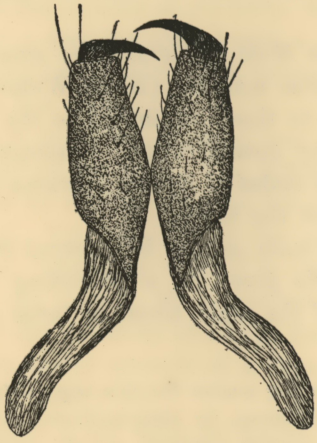

FIG. 8. Poison apparatus of *Latrodectus mactans*, male. Magnified 34 times.

An attempt to determine the effects of the bite of the male on rats was made on November 26 and December 3. The test was conducted essentially like those made with the female spiders. The first difficulty that presented itself was that the male is not so easily held because of its small size. Furthermore, its fangs are rather small, and are entirely hidden behind the large bulbs of the palpi. By the use of a binocular loupe, magnifying about four times and a small camel's hair brush, the latter difficulty is largely overcome. The male is a timid and diffident creature; no amount of teasing or persuasion would induce him to bite. He either could not or would not bite. Thinking that even the short hairs (on the inside of the leg of the rat) were in his way, I tried to induce him to bite on the inside of my small finger. This, too, was in vain. All the response that he made was an indifferent nibbling.

The evidence in regard to the poisonous properties of the male *Latrodectus* is therefore left incomplete, and far from conclusive. The presence and the size of the glands indicates that the male is poisonous; but his actions indicate that he uses the fangs only for seizing prey and is therefore entirely harmless.

PETROLEUM

By Professor MARSHALL HANEY
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Introduction

Petroleum is absolutely necessary to the age in which we live and one of the most important substances used by society to-day.

Cotton, steel and coal are of vast importance to us, but they can not compare in importance with petroleum, the only source from which lubricants can be obtained in sufficient quantity to smooth the wheels of industries.

Without lubricants the railroads could not operate, nor could steamships sail the seas. No industrial plant could run its machinery, and the crops on the farm would have to rot where they grew, because the wheels of the humble farm wagon must be lubricated, while the farm's motor truck must have gasoline and lubricating oil. Petroleum is also the sole source of gasoline and, in addition, it provides kerosene. Statistics show that 95 per cent. of the world's population uses kerosene as an illuminant. In large cities only 25 per cent. of the total of the houses are lighted by electricity, and electricity could not be produced unless the bearings of the engines and generators in power plants of central stations were generously supplied with lubricating oil. Fuel oil, one of the products of petroleum, is a vital necessity for ships of the navy which protect our shores, and our new merchant marine uses it as a fuel.

Historical Outline

All the early races which inhabited the earth knew of petroleum and used it. The word itself is made of two Latin words, *petra* (rock) and *oleum* (oil). It means rock oil. Its first use is lost in the darkness of antiquity, but we know that the builders of Babylon used asphaltum, a residue of petroleum, to bind together the rocks from which the city was built. The Babylonians secured the asphalt from the fountain Is on the Euphrates, and this fountain attracted the attention of the early emperors Alexander, Trajan and Julian. Herodotus describes a spring on the island of Zante from which the Egyptians obtained a supply of the same substance used in preparing their mummies.

The Greek historian Descorides Pedaners tells us that the citizens of Agrigentum in Sicily burned petroleum in lamps long before the birth of Christ. The Persians for centuries burned it in

their lamps, and the Hindus in India used it as a preserver of timber and in the cremation of corpses. The Incas in Peru and the Aztecs in Mexico used asphalt for architectural purposes. The first settlers of Pennsylvania found the Indians using petroleum as a medicine, as a paint when mixed with bright red and yellow mineral earths and as a timber preservative.

Three miles above Oil City, Pennsylvania, there was a remarkable oil spring in the middle of Oil Creek. From the rocks and gravels in the creek bed oil would rise in large globules and would spread over the surface of the waters. Nathaniel Carey dug and walled shallow holes in the creek bed, and as the oil rose on the still water in these pits it was collected by skimming and sold as "Seneca Oil" for 25 cents a gill. In all probability this was the first sale of crude petroleum in the United States. Before this time the white settlers followed the Indian custom of collecting oil by spreading blankets on the springs, allowing the blankets to become soaked with oil and then wringing them out.

The early settlers secured their salt from brine pumped from wells. These brines in West Virginia, Kentucky, Tennessee and Pennsylvania were contaminated with petroleum. Samuel Kier, a druggist of Pittsburgh, whose father worked some of the salt wells on the Allegheny River, knew of the medicinal value of the oil and succeeded in working up a large trade in "Kier's Petroleum," selling two barrels a day at $1.00 per pint. For illumination our forefathers had been using beeswax, tallow, candles or sperm oil. The heavy smoke and strong odor rendered petroleum at first unfit for an illuminant. In 1846 Dr. Abraham Gesner discovered a new illuminant made by distilling coal, obtaining an oil he called kerosene or carbon oil, and it was popularly called "coal oil"; even in recent years we hear kerosene called "coal oil."

Dr. Gesner patented his distilling process in 1854, and his new illuminant sprang immediately into favor and was so much more in favor than fish oil that it practically destroyed the fish-oil industry. The demand was so great that the refineries could not produce this oil fast enough to meet the demand, and the price rapidly advanced to two dollars a gallon.

It was generally believed at this time that petroleum contained an illuminant identical with "carbon oil," which led to attempts to distil it.

Samuel Kier, experimenting in 1848 with a kettle and wooden coil, succeeded in obtaining from petroleum a product which he sold as carbon oil for $1.50 a gallon.

James Young, of Scotland, patented a process for obtaining paraffin wax from petroleum by distillation, and in 1853 Aaron

Robbins, of Meadville, Pennsylvania, developed a still having a capacity of a barrel of crude oil a day, which was soon enlarged to a capacity of 100 barrels of petroleum per day. The only product Robbins made an attempt to save was the burning oil, which he called headlight oil, and the petroleum he used was imported from Canada.

Twelve barrels of carbon oil obtained from petroleum were shipped from Pennsylvania to New York in 1857, and this shipment created a great demand for petroleum.

Prior to the year 1858 there had been many attempts to dig wells with pick and shovel down to bedrock which, at that time, was considered to be the source of petroleum. Prior to 1859 nobody had succeeded in reaching bedrock with an open well. Edwin Drake tried to dig a well through the clay and quicksand near the oil spring. He finally succeeded by driving a pipe to bedrock and then removing the material from the pipe and then continued to drive into the bedrock until he reached a depth of 69 feet from the surface on August 27, 1859, and this well produced twenty barrels per day.

Drake's method of sinking wells was immediately adopted, and many other wells were sunk as soon as his success was known. The oil obtained from these wells was stored in whiskey barrels containing 42 gallons, and this unit of measure has been retained.

Periods in the Industry

The use of petroleum as an illuminant started in 1859, and for many years afterward kerosene was the only product sought. By the summer of 1861 the production of petroleum had increased to 1,500 barrels per day, and by the early part of 1863 it had increased to 15,000 barrels per day. During the period of the Civil War production declined.

With the introduction of automobiles a demand for gasoline was created, and at the present time the demand for this material, which was once regarded as waste, has become more important than kerosene. The period from 1909 to date may properly be called a gasoline period, and at the present increase in the use of fuel oil it appears as if we might be entering a fuel oil period.

Barrels of Petroleum marketed in U. S. from 1859 to 1920

1859	2,000 barrels
1869	4,215,000 "
1879	19,914,000 "
1889	35,163,000 "
1899	57,070,000 "
1909	183,170,000 "
1919	375,559,000 "
1920	443,402,000 "

The above table shows the rapid increase per year in intervals of 10 years.

Oil Fields in the United States

There are seven oil-producing areas in the United States which, described in their order of original discovery, are as follows:

The Appalachian Field: The pools in this field have never been abandoned or exhausted, and there are producing wells to-day close to Drake's original well. This field extends along the western slope of the Alleghany Mountains and includes Pennsylvania, Ohio, New York, West Virginia, Kentucky and Tennessee. The development in this field began in 1859; it reached its maximum production in 1900, producing 36,000,000 barrels, and in 1920 it produced 30,511,000 barrels.

The Mid-Continent Field is the most important oil field of to-day. It includes Kansas, Oklahoma, central and northern Texas and northern Louisiana. The maximum production was 249,074,000 barrels in 1920.

The Lima-Indiana was opened in 1884 in Ohio, and the maximum production was 25,000,000 barrels in 1896, and in 1920 it produced 3,059,000 barrels.

The California Field was discovered in 1899, and the oil in this field was originally used for fuel because it contained very little gasoline and kerosene, but in recent years deep drilling has produced a high grade oil. In 1920 its production was 105,668,000 barrels.

The Gulf Field includes many pools in southern Texas and Louisiana. It became prominent in 1901 and reached its maximum production of 36,000,000 barrels in 1908 and in 1920 it produced 26,801,000 barrels.

The Illinois Field consists of many scattered pools in the state of Illinois. Important developments began in 1905. The maximum production of the field was 36,000,000 barrels of oil in 1908, and in 1920 it produced 10,772,000 barrels.

The Rocky Mountain Field is located on the eastern slopes of the Rocky Mountains in Wyoming, Montana and Colorado. The maximum production of this field was about 140,000,000 barrels in 1920.

The rank of the fields in 1920 with respect to the quantity of oil produced was:

Mid-Continent	249,074,000 barrels
California	105,668,000 "
Appalachian	30,511,000 "
Gulf Coast	26,801,000 "
Rocky Mountain	17,517,000 "
Illinois	10,772,000 "
Lima-Indiana	3,059,000 "

Until 1885 the Pennsylvania field produced more than 98 per cent. of the world's supply of petroleum. The Russian production began to be commercially important in 1869 and by 1892 it exceeded the production of the United States, reaching its highest point in 1901. The United States forged ahead in production, however, until we now produce 64 per cent. of the world's total. Mexico's production grew rapidly and to-day it ranks next to the United States.

Climate

The climates of the past are of prime importance in the development of abundant life and consequently would be among the determining factors in the distribution of the petroliferous areas. To have petroleum there must be a source and, since living matter is considered the source of petroleum, geological conditions must have been such that living organisms were abundant. The arid regions have not given rise to living things in sufficient quantity to produce oil; also the same is true in cold regions and inbound lakes. To produce an abundance of living organisms warm, moist conditions must prevail.

Before an area could be considered a petroliferous province, it must have had an abundance of living things from which the oil was formed. By studying the earth's surface one will be impressed with the fact that all the important oil fields lie between 20° and 50° north latitude and of course are restricted to this range of climate.

The Origin of Petroleum

The probable origin of petroleum in the earth has given rise to much discussion. It has been found by laboratory experiments that hydro-carbons may be obtained from organic substances and, likewise, from certain of the inorganic substances. From fish oil, hydro-carbons which are similar to those obtained from the earth have been obtained by destructive distillation. Wood and vegetable oils have been shown to yield hydro-carbons. From cast iron spiegeleisen and ferro-manganese, when dissolved in a mineral acid such as hydrochloric, there is evolved hydrogen and small quantities of hydro-carbons. It is a matter of common knowledge that most carbons react with water to form hydro-carbons.

The theories as to the origin of petroleum in nature that have been proposed may be divided into those that ascribe their origin to inorganic substances and those that recognize an organic source for petroleum. The inorganic theories are diverse, but the best known involve an assumption of the existence of carbides deep within the earth, from which hydro-carbons are formed.

The organic theories are those which ascribe the origin of petroleum to animal sources, those that ascribe the origin to vegetable sources, and those that ascribe the origin to vegetable and animal sources combined. The theory of origin from animal sources maintains that the petroleum originates from the slow decomposition of the fatty substances of animals imbedded in the rocks. Those who regard petroleum as derived from vegetable matter for the most part name the lower plants as the probable source, including the cellular marine. Those who recognize that the petroleum oils may be derived in part from animal remains and in part from vegetable substance sources are in majority at the present time.

The geologic relations of petroleum deposits supports the organic theory of its origin. The diversity of the petroleums and the varying kinds of sedimentary rocks with which it is associated argues for the probable derivation in some instances from animal remains and at other places from plant remains, or, in other instances, from animals and plants imbedded as they often are in the same formation.

In the application of geology of the location of petroleum deposits, the organic theory of origin is very generally applied, and deposits high in the organic matter are universally sought as one of the conditions favorable to the accumulation of oil in commercial quantities.

The Accumulation of Oil Gas into Deposits of Commercial Value

At first, the organic materials in the rocks were widely disseminated, while the oil as found in nature is usually segregated into restricted areas.

Migration of Oil

It is a generally accepted conclusion that oil and gas as obtained commercially have migrated more or less from the original source. The forces that influence migration include specific gravity, capillary attraction, perhaps some others not fully understood. The well-known difference in specific gravity between oil, gas and water are among the important causes of the separation of oil, water and gas.

As oil is lighter than water it naturally rises to the top and hence tends to segregate in the rock above the water line. Gas naturally tends to accumulate at a level above the oil. In an inclined stratum capped by an impervious rock the oil and gas migrate up to a higher level than the water. The capillary attraction is a force that plays an important rôle in this migration. The cap-

illary attraction of oil is less than that of water; hence it is assumed that water, through capillary attraction, may force oil from rocks having small pores, such as shales into rocks having larger pore space, such as sand stones.

No doubt the compacting of sediments by their own weight is an important factor in compelling movements of included fluid; other causes are increased temperature, as sediments accumulate affecting the fluidity of the oil. A reduction of the pore space in the rock by cementation would compel migration.

The Storage of Oil

The migration of the oil in the rock will affect its segregation in commercial quantities only when the natural storage conditions are suitable. The rocks are capable of holding a gas or liquid in proportion to their porosity, and any rock that is porous may, under favorable conditions, serve as a reservoir. As a rule, sands and sandstones are high in porosity and much of the oil secured is taken from sands or sandstones, but not all sands and sandstones are sufficiently porous to serve as reservoirs, nor is the same horizon as a rule uniformly porous.

Locally, the pore space in the sandstone may be partly or wholly filled with a cementing substance, thus reducing or destroying the pore space and, at the same time, destroying the storage capacity of the rock. Limestone frequently stores large quantities of oil and gas in the pore space incident to shell breccias or in solution cavities. Dolomitic limestones are often notably porous rocks. Shales, which are the source of much oil, have themselves a very limited storage capacity, owing to the fine texture of the rock.

Geologic Structure Favorable to the Accumulation of Petroleum

The migration of oil due to various causes into porous rocks is not of itself sufficient to bring about accumulation of oil in large quantities, except in localities where the structural conditions are favorable. If a rock is uniform in porosity and horizontal in position, it may contain a considerable quantity of oil and gas and not afford favorable conditions for segregation of oil or gas in commercial quantities.

In nature it is rare to find a rock uniform in porosity or entirely horizontal in position, and, as a rule, they vary very much in porosity and departure from the horizontal.

Favorable structural conditions are those which bring about segregation of oil and gas in commercial quantities and such conditions are very varied and difficult to classify. A number of the best known conditions favorable for the accumulation of oil may be described.

An Inclined Porous Stratum

It has already been stated that rock formations rarely, if ever, lie entirely horizontal in the earth and that inclination from the horizontal is a very common condition. The effect of departure from the horizontal in a formation containing oil will be apparent. If the stratum contains both oil and water, the oil will be forced by the water up the dip. In such inclined strata, there is no obvious trap to retain the oil and, if the pressure of the water is sufficient, all the oil will be driven out of the strata at the surface as an oil seep.

Reduction of the porosity of the rock near the surface may retard the movement and form a trap to hold the oil at a definite level. In case of an inclined stratum of this kind, when the necessary variation in porosity to form a top is lacking, the oil extruding from the surface for a time may deposit a heavy residue in the pores of the sand upon evaporating to such an extent as to cement the sand and thus form a trap for the retention of the oil.

Folded Strata

Instead of being merely tilted, the rock strata may be folded in such a way as to form a trap to retain the oil. As a general rule the folding is more or less complicated.

Anticlinal Folds

As a rule in nature an upfold is more or less complicated by a downfold called a syncline. The oil and gas moving up on reaching the anticline may be trapped and accumulate until the anticline fold is filled, if there is sufficient oil and gas to fill it.

If the stratum contains water, it will be in the syncline and if no water, the oil will be in the syncline. Folds in rocks may be symmetrical in form or lacking in symmetry. Unsymmetrical are the most common. The folds in a formation may extend in the direction of the dip or across the dip, depending entirely on the conditions bringing about the fold.

Faults

Very frequently, faults bring about conditions favorable for the storage of oil. The movement of certain portions seals the formation along the fault plane, thus creating an oil reservoir.

Domes

In its simplest form an anticline is an upfold or arch in the strata or may be thought of as a bulging up of the strata. Domes may be, but are not necessarily, accompanied by compensating structures known as basins. Domes serve as an ideal trap for oil

and gas as they are closed on all sides. They form a sealed basin in which the oil is retained. A very exceptional type of structure is known as salt domes and they are frequently oil-bearing near the Gulf of Mexico, and the central portions of such domes consist of a mass of salt; in some of the domes the salt core comes nearly to the surface. Overlying the salt is anhydrite and above the anhydrite a mass of sulphur.

The cap rock is generally limestone and, above this, clays, shales and other sedimentary rock. The process by which such domes were formed remains undetermined.

Their importance as oil reservoirs arises from the fact that salt and associated minerals have pushed up the sedimentary rocks resulting in a dome structure favorable for the accumulation of oil and gas.

Volcanic Plugs

Volcanic plugs or intrusions coming up into sedimentary in some instances push up the strata in such a way as to form storage reservoirs for oil.

Depth of Wells

The question often heard is the depth to which it is necessary to drill to obtain oil. The question in all probability is prompted by the supposition that oil can be obtained at any place, provided drilling is continued to sufficient depth, but such is not the case; in some localities oil is obtained at a very shallow depth, while in other parts of the earth it is not reasonable to expect that oil can be obtained at any depth.

In some locations, oil has been found in commercial quantities at a depth of 100 feet or less and, on the other hand, many wells produce oil at from 4,500 to over 5,000 feet. In drilling, the cost increases rapidly with depth, and only wells that are large producers repay the expenses of deep drilling; on the other hand, shallow wells producing a small quantity are profitable.

Surface Indications

Oil in many instances is indicated by oil or gas seeps at the surface. It is not to be assumed that seeps at the surface in all cases indicate oil in commercial quantities below the surface. On the other hand, oil below the surface in all cases does not outcrop at the surface, and many valuable oil pools have been located with no surface indications in the way of oil and gas seeps.

Many of the oil and gas seeps on investigation prove to be something other than oil and gas: Iron oxide scum is very frequently mistaken for an oil scum; when an iron scum is broken it forms

angular fragments which do not readily unite, while, on the other hand, an oil scum breaks in round fragments and readily unites. The oil scum is not readily removed from the hands by washing, while the iron scum is readily removed on washing.

Other gases than petroleum gases are found at times coming from the earth, such as carbon dioxide and hydrogen sulfide.

Most of such gases are non-inflammable and can be recognized by their odor. Inflammable gases coming continuously from a strong flowing spring are likely to be coming from a considerable depth and can be regarded as favorable indication of oil or gas.

Geologic Investigations

The object of geologic investigations should be to determine whatever should be made known in regard to the property in advance of drilling or in addition to drilling, as the case may be. In these investigations the geologist will take into consideration the character of the underlying formations or sediments, whether petroliferous or not, and the probable depth of the producing horizons, if such are believed to exist.

In determining probable structural conditions, evidence as to the position of the strata may be obtained by observations on the surface formations determining the direction and amount of the dip. Surface topography must be used with care in determining underground structures; only occasionally do hills coincide with anticlines.

In examining a property the geologists will take into consideration all structural features that can be determined. The character of a portion of the underground rock can be determined from cullings from wells previously drilled or may be inferred from outcroppings of formations coming to the surface some distance away. Oil and gas seeps would indicate petroliferous formations, but are not the only indications and are by no means always present, even in areas underlaid by oil and gas.

Methods of Drilling

The two common methods in use for drilling wells are the rotary and the percussion drills. Rotary drilling is practicable where the formations to be drilled through are relatively soft but operates at a disadvantage in a hard formation.

The percussion drill is used to advantage where the formation is hard. In the percussion method drilling is by means of a heavy drill, which is alternately lifted and dropped, thus breaking or pounding its way through the rock. The broken or pounded portions of the rock are removed by a bailer, the rock material being suspended in water. For a large cable rig such as is necessary for

deep wells, a derrick is built on the well site by which to support and handle the machinery.

The rotary method is entirely different from that by cable tools. In the rotary drill a string of pipe extends from the top to the bottom of the well, the pipe revolves and cuts into the rock. The loose pieces of rock are floated to the surface by means of a stream of water which is carried into the well through the drill stem and back around, that is, outside the pipe. The cable method is generally used when drilling in new territory, due to the fact that the character of the rock is more readily determined when drilling by cable than rotary.

In new territory, to fully determine the character of the formation, the use of the diamond drill is advisable, and by this means a continuous core is taken in the hard rock formation which is of inestimable value in prospecting for oil and gas.

Composition and Properties of Oil and Gas

The petroleum compounds, oil and gas, are natural products found within the earth, composed essentially of hydrogen and carbon. In addition to hydrogen and carbon there may be present in oils a small amount of nitrogen sulphur and oxygen.

The petroleums found in nature, although consisting of two essential elements, are of extremely varied composition and have been shown by chemical analysis to form compounds which may be arranged in several series, and of each series there are many members. The more common petroleum compounds are those which are included in the paraffin, olefine and napthene series.

Less common in nature are compounds of the acetylene and benzene and several other series. The petroleum compounds of the paraffin series, also known as the methane series, consist of hydrogen and carbon combined in certain definite ratios. In the following table is given the name and formula of the common gases and oils of the paraffin series. The first four of these are gases under ordinary conditions.

Name	Gas	Formula
Methane	"	CH_4
Ethane	"	C_2H_6
Propane	"	C_3H_8
Butane	"	C_4H_{10}
Pentane	Oil	C_5H_{12}
Hexane	"	C_6H_{14}
Septane	"	C_7H_{16}
Octane	"	C_8H_{18}
Nonane	"	C_9H_{20}
Decane	"	$C_{10}H_{22}$

In the olefin series there are, in all cases, twice as many hydrogen atoms as there are of carbon atoms. The general formula of the series would therefore be CnH_2n.

Paraffin Base and Asphalt Base

Certain of the petroleum oils, particularly those of the paraffin series, upon evaporation leave a paraffin residue. Other petroleum oils, including those of the olefin and napthene series, upon evaporation leave asphaltic residue.

Accordingly in commerce, petroleums are commonly known under these two main divisions: namely, those having a paraffin base and those having an asphalt base. The asphalt in oils is said to be due to the inclusion of sulfur and oxygen compounds in the oil.

The petroleums of a paraffin base are of more value for refining purposes than are those having an asphalt base. Hence, the classification of oils as of paraffin base and asphalt base is of commercial value.

Specific Gravity

The specific gravity affords an important aid in judging the quantity and value of oil for refining purposes, the lighter oils as a rule being more valuable than the heavy oils. Since the oils are lighter than water the actual specific gravity expressed in the ordinary way is less than one.

In ordinary uses a special scale has been devised known as the Baumé scale, in which the gravity is expressed in whole numbers. On the Baumé scale, distilled water at 60° F. has a gravity marked as 10°, and the figures on this scale are so arranged that they increase as the gravity of the fluid decreases.

Paraffin base oils are usually light and hence on the Baumé scale have a higher reading than asphalt base oils. The color of crude oil varies from light yellow or straw color to black. As a rule, oils of light color are likewise light in gravity. The odor varies decidedly, depending in all probability on the included gases. Hydrogen sulfide gas is often present in the oils from limestone, giving a disagreeable odor. A tropine odor is often detected in light-colored oils. Aromatic odors and an odor of gasoline characterize some of the crude oils.

Another property in which oils differ much among themselves is viscosity or fluidity.

As a rule the light or paraffin base oils flow readily. Some of the heavy oils are so viscous as to require heating somewhat before they can be pumped through a pipe line.

The Refining of Oil

Crude oil is received at the refineries from the pipe line or from tank cars and is generally stored in 55,000 barrel steel tanks. There is no average size for a refinery, and they vary from 50 barrels per day to thousands of barrels per day. In general, the larger the refinery the more efficient and economical the operation.

When petroleum is heated, it begins to boil at a temperature so low that the heat will not injure the skin. It is not the whole of the petroleum which is boiling, only the lightest part, that is, the gasoline or naphtha. If the temperature is held constant for a short length of time all the gasoline would have boiled off; with the temperature remaining the same the boiling will close.

If the temperature of the oil is raised to some higher figure it again begins to boil, and now it is the kerosene constituent of the crude petroleum which is being converted into vapor and driven out of the liquid. After a short period the kerosene will be gone and as before the liquid will cease to boil.

In this manner the various constituents of the petroleum will be separated one from another.

The apparatus employed for the purpose of separating the oils is called a still, and these stills have been developed to a large capacity, some of them holding 50,000 gallons or more. In such stills the temperature of the crude petroleum is gradually raised and with each elevation in temperature a different product is boiled off until finally nothing remains in the still except a small quantity of black residue known as petroleum coke.

The cooling and condensation of the vapors is accomplished by means of an apparatus called condensers, which is connected to each still. This consists of a coil of pipe submerged in a tank of cold water. The vapor coming from the still is cooled and condensed to a liquid condition in passing through this worm.

The fraction which has the lowest boiling and is, therefore, driven off first is the gasoline, and the character of the condensed liquid delivered by the pipe from the condenser coil to the house will automatically change the connections in the receiving house so that the next distillate will be received in a separate tank. The second distillate which comes into the receiving house and is thus diverted into a separate tank will be the illuminating oil. In the early days of the industry everything was practically waste except kerosene.

The next product driven off after the illuminating oil is a somewhat heavy and discolored free-flowing oil called gas oil. This oil is seldom sold to the retail trade, as its chief use is for the manufacture of city gas. Most refineries make a cut in gas oil, separating it into a high quality and a low quality gas oil.

The next product after the gas oil and the last important product of crude petroleum is the lubricating oil. The paraffin is separated from the remaining oils by chilling the mass in a refrigerator apparatus and there pressing the oil out of the mass.

TANKERS

The close connection between petroleum and maritime commerce was assured from the day the United States was recognized as the chief reservoir of the world's supply. The function of the old whaling ships is now performed by the modern oil tankers.

The modern tanker dates from the launching of the Atlantic on the Tyne in August, 1863. This was the first ship designed to carry oil in bulk. The first ocean-going ship to be fitted with iron tanks for the transport of petroleum and to be equipped with pumps for unloading was the Charles, a Belgian ship. This ship was fitted with iron tanks estimated to carry 7,000 barrels of oil, and this sailing vessel plied between New York and European ports from 1869 to 1872.

The rapid growth of the industry in the eighties proved that the converted oil ship was not economical, and this led shippers to demand an improved tanker bill in such a way that absolute control could be exercised over the oil, a demand which resulted in the construction of tankers free from risk of waste and dangers. In contrast to the Belgian ships' capacity, the larger types of modern oil tankers will carry more than 4,500,000 gallons.

The larger petroleum organizations do not depend on private shipping firms to carry their products, but build their own vessels. A few years ago it required days to load or unload a 10,000 ton ship. This task is now completed in a few hours, being handled by use of powerful pumps. Due to the rapidity of loading and unloading oil ships do more sailing than any other class of ships. In transporting crude oil short distances by water, barges are used.

THE TIME OF DAY

By Professor ALFRED H. LLOYD
UNIVERSITY OF MICHIGAN

SECOND PART[1]

VIII

BUT, to forget Bunyan and Christian and perhaps in more senses than one to come really back to earth, our present-day materialistic realism is beginning to appear in a different character from that often if not usually assigned to it. It is only "carrying on" for what was, expanding and liberating the past. The traditions of a long history, already traced here in several ways, are actually discoverable in it. It fulfills, not supplants, the past. True, to face the case at its worst, even consciousness and will are now said to be physical. The soul itself, if any longer one may use the word at all, is said to be physical. Yet, this granted for argument's sake, even for candor's sake, and all that Freud would insist on added just for good measure, the physical world is no longer what it was and much of our time's materialism is merely an amazing anachronism. Our history-ignorant materialists suggest to me a man having an unpleasant name like Gottesliebe or Himmelhoch and actually delighting in its rudeness until one day learning its true meaning. Thus, whatever the physical world was centuries ago,

[1] The first part of this essay appeared in the November number. After urging that it was very important to-day that the time of this twentieth century be told, not by mere boastful dates, however large and nobly round the figures, but by weight of actual conditions and opportunities, the writer represented the century as weighted with at least three important things: (1) Anthropology, the intimate and naturalistic and scientific study of man, including psychology, now so cordially in the company of such sciences as botany and zoology and physiology, and psychiatry, now at least presuming to give most sensuous and realistic, if not materialistic, "close-ups" or exposures of man even to his very soul; (2) technology with its amazing development of standard methods and external automatic machinery, and (3) new and great adventure. The anthropology was shown to be fourth in a sequence of intellectual interests marking great eras of Christendom: theology with the dogmatic institutionalism of the medieval church, mathematics and mechanics in the seventeenth and eighteenth centuries, biology in the nineteenth with its epoch-making evolution-hypothesis, and to-day the intimate and at last wholly unreserved science of man. Furthermore, so recounted, the great story of Christendom from a narrow supernaturalistic institutionalism, holding man quite aloof, to the present broad naturalism was interpreted as indicating on a grand historic scale man's gradual adaptation to the natural environment and as implying mergence, not

astronomy, mathematics, biology and psychology have greatly transfigured it, actually bringing into it or revealing out of it, as we shall see, facts or opportunities once associated only with the spiritual aloofness of the orthodox religion and its church. For, being at once naturalistic and intimately anthropological, science may indeed be giving us that "close-up," even to startling and offensive exposure, but therein, instead of only the surrender of all that is ideally human and humanly treasured to what is natural and unpleasantly physical, there is at least with as much truth a transfiguration of physical nature. Poor is the rule, as you know, that does not work both ways. Not more has matter taken spirit to itself than spirit matter. Who really examines the evidence, for example, translating the German, so to speak, will find that by the very science of it the whole life of sense from being blindly instinctive and close, immediate and uncontrolled, is to-day positively and openly on the whole under more actual constraint than ever before in the whole history of Christendom. Any other conclusion would be only self-deception when not downright dishonesty. Violence is naturally so much more obvious than law and order and so much better as a "story" whether to the writer for the newspapers or to other materialists and sensationalists.

Listen! To-day, if someone says the room is cold or hot and another is of different opinion, how is the question settled? By the thermometer, as inconvenient and standardizing to personal feeling and judgment as the church of old. A young mother living not far from Ann Arbor, for very excellent cause was once prompted to give her son a vigorous spanking. Did her anger and its quick circulation and nervous condition get the better of her? Not at all. Being modern and objective and "materialistic," being also although only in spirit ecclesiastical, she first took his temperature in

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necessarily loss, of all that had been spiritual in the natural or physical. It indicated also, as the ruling idea of a theocratic institution gave way to that of natural mechanism, mechanism to organism and organism finally to the conscious and willing individual of present science, a process describable as expansion of life and "liberation of the spirit." And, lastly, it revealed a moral progress, a pilgrimage, in which Christendom appeared as journeying midst many adventures and hardships, not after Bunyan from this world to the next, but from that other next world so predominant for human interest in the middle ages, to this, now so absorbing and, thanks to the intimacies of anthropology, so sensuously real. Finally, if really meaning such adaptation and expansion and liberation, the day's materialism, its direct and unreserved naturalism, might not be as unspiritual as very commonly supposed. Some assurance was to be got, too, from Bunyan himself and the orthodox sensuous realism of his very account of Heaven and its sensuous glories. Moreover, he saw that "there was a way to Hell even from the Gates of Heaven." Possibly even the feared and to many distressing naturalism of our twentieth century, if faced and understood, in its turn will show a spiritual path.

order to be sure that illness instead of punishable obstinacy were not the source of his obstreperousness. Alas, his temperature proved normal. Curtain! Could a Father Confessor have been more considerate or as deliberate? Ghosts of the medieval church! Hovering over our modern "physical" life! Moreover, besides thermometers we have thermostats, the temperature by institutional authority for much of our life to-day.

Nor is the "stat" principle, which always makes for standardization, by any means confined to our temperature sense. It has been applied and is getting every day more refined as well as more elaborate and more comprehensive in its application to every phase and department of our life, sensuous or rational. Under our modern scientific and anthropological realism—I all but misspoke and said ecclesiastical instead of scientific!—we are indeed and are, as never before, members one of another in a standard life. Even our breakfasts come in uniform packages under trade-names. According to Hugh Walpole, recently lecturing in this country, our very novels to-day are more generic than friendly and human and personal. In a current journal I find—observe carefully this title[2]—"A statistical study of ethics" in which are tabulated certain more or less common practices "in order of worseness," sex irregularity, stealing, cheating, and so on, the mathematically graded list ending in smoking, next to last, and dancing, at least relatively innocent and last.

What, pray, are we coming to? Rather, where have we come? Essential institutionalism and standardization! With such ethics, with thermometers and their sort, with all the modern "stats," with mental tests or personality measurements and ratings, of which we heard so much during the war and have at least not ceased to hear a good deal since, with our new methods of examination and classification, whether for college or for life, so empirical and statistical in method, so definitely standardizing and allocating in results, with these and much else in kind, all of course, as we may infer, for some wonderful mobilization, we shall soon be all labeled as but so many models of certain letters or numbers, Model A or B, Model 13 or 23, and among other consequences our various institutions of education will enter upon an era of standardized quantity production and in due time may make important contribution to the setting up of a hierarchy never yet even distantly approached for efficiency and accomplishment. To biological or physiological eugenics, which would "scientificize" and perhaps Mendelize the family beyond even Plato's dream, we shall have added something

[2] "A statistical study of ethics," by Professor A. P. Brogan, University of Texas, in the *International Journal of Ethics*, January, 1923.

of the same general sort in the regions of mind and spirit. Already I have boldly quoted a future historian. May I now read from a morning paper of some years, never mind how many years hence:

> Yesterday, Commencement Day, was a record-breaker in the life of the college. The orator of the day spoke impressively on "Scientific institutionalism or efficient gradation and quantity production in the things of the spirit," and at conclusion of his most eloquent and stimulating address labels were placed on more graduates in the higher models than ever before. Only in Model 13 was there any falling off. Names and figures follow.

In a word, thanks to science and its realism, which no longer spare the sanctuary of man and his nature and which in spite of our mood for laughter we must take seriously, even "remaining to pray," standardization and quantity production in the human product, as in automobiles, are of the spirit of the time, and it is a safe prediction that, for better or for worse, we are only in the earlier stages of the amazing enterprise. In still another word, too, thanks to science being evidently but the widely liberated spirit of ecclesiasticism, being this spirit opened and deepened for larger and fuller life, "you may break, you may shatter" the medieval régime, "if you will," but the mechanical efficiency, the uniformal constraints and the pyramidal, hierarchical classifications or gradations, as well as the great underlying purpose—alas, long ago I lost the meter, yet not the rhyme!—"will cling to it still."

IX

We are, I think, beginning to understand our modern physical world so-called and the spiritual possibilities of it. This world the day's psychology would have our souls "join" and our souls, having cherished memories, have hesitated. But let me go on. Still more can be told. Ours is in truth a life of sense, of seeing and hearing, of instinctive passion and desire; it is, too, such a life under constraints of uniformity and impersonal standards, as the thermometers and the thermostats were showing us; but, more than this, also with benefit of science it is rapidly becoming world-wide in its actual and sensuous reach; it is near to being—what is the great word out of the past?—ecumenical, that is, comprehensive of the inhabited world. I was saying that the big things of life had somehow made the world small. We used to look out of our windows and see the things of our own yards or streets or hillsides or from those windows hear only what our unaided ears might get. Now, with benefit of the same standpoint and methods of science which are dictating to mankind a naturalistic realism, our eyes and our ears may reach, not just in imagination, but sensuously, what

in rest or in motion belongs to regions far away, even around the world. The very curvature of the earth no longer obstructs. Moreover, others far away share with us sensuously, realistically; I mean audibly, visibly. Not only in the specific sense, but more generally, not merely literally but figuratively "broadcasting" and its ecumenical realism belong to our day, the great heritage of our generation. Very recently I was reading a paper giving report of Edouard Belin's promise of television. Add broadcasting to that! The newspaper, the telephone and the phonograph, color photography and motion photography, the wireless and the radio even as we know these to-day, may soon seem insignificant beside what is coming. Still, apart from all rash prophecy, the present day offers quite enough to indicate clearly what the materialism and the realism of our time may mean. Time and space no longer set limits to our senses. With no mere personal glasses or ear-trumpets are we having real experiences beyond our unaided powers, but with an increasingly efficient general and standard instrumentation of life we are, not playing at sensing, but actually sensing the whole world. Let me say even once more, yet with fuller meaning, that we are become in no mere fanciful or sentimental way members one of another. How wonderfully physical, how golden withal and musical, how shiningly real is become the possible life of the human spirit.

Am I forgetting something? Doubtless. But, specifically, psycho-analysis? As well as what according to the librarians are at least among the most soiled books on the shelves? Am I forgetting the primitive—or primary?—instincts of nutrition and reproduction, the passions and desires, that no institutional life or no instrumentation proceeding from science can ever successfully suppress, can ever suppress without disaster to body and mind? Am I forgetting the evidence that these afford for a raw and wholly unspiritual realism and that has apparently been inspiring many recent novels and dramas as well as much else in our art and literature and pretended morality? Not for a single moment. The evidence, as frequently it is taken, is fallacious. Why expect successful suppression? For a word so misleading if not actually treacherous I would substitute instrumentation or mediation, that is, informed and purposed control, as at once more natural and more scriptural. I would also suggest—expecting to be understood—that the mediation or, say, the controlling instrumentation just for morality's sake be enlightened and up-to-date, that is modernly, not medievally, scientifically not just traditionally and legalistically, institutional. Why be behind our times in what is so fundamental to the very life and urge of all times? Or, on the

other hand, why be a raw realist and materialist, soiling life as well as those books, when the very science which has written the books means, if in spirit and methods and results it mean anything, objective and ecumenical standards, in short, social control, not just personal license? Why not see those passions and desires, no longer in the abnormal complexes incident to a too medieval suppression, but in the normal and safely controlling complexes of life to-day as with our wider view and greater understanding, with our natural laws at once more obligatory and more dependable, with our wiser and safer candor,—which we must avoid confusing with deliberate exposure, and with our general broadcasting life is being lived? Why by too much conservatism actually invite disastrous license instead of promote real freedom?

An automobile was wrecked in our street a few days ago. I inspected the ruin, talked with the humiliated as well as injured driver, and concluded that, forgetting himself and lapsing consciously he had had a Freudian or at least some very modern dream of driving old Dobbin and a buggy on some country road. If we will but bring our life of sense, instinctive as well as more conscious and intellectual, up to date, treating it as by no means immediate and loosely free but mediate and controlled with world-wide contacts, we need take no alarm for morality from our time's realism, scientific and ecumenical. At least morality and hygiene, whatever may transpire for politics and economics, may have benefit of the big things that have been making the world small and compact. Even hunger and sex are now in world mediating and controlling complexes.

Once more I am in my one-time host's dining-room, and in the color of the walls at last I do see the intriguing primary coat. Intimately, in the scientific and naturalistic anthropology and psychology of to-day or in the materialistic realism, which they dictate, and which gets its sensuous and physical reality through the broadcasted experiences of the inhabited world, I feel, and would have others feel, subtly but really, spiritually not literally, the great past of Christendom as this from its beginning has been expanded and refined in those successive stages of theology, mechanics, biology and finally anthropology.

How hard it is to-day to get away from the telephone! Or to do without it! In a now relatively small way the ordinary telephone may remind us how far and how concretely our selves reach to-day. Talking to Europe by wireless is getting to be an old story. A good deal of water has gone under the bridge since the prophetic William James, always given to picturesque ways of expressing great principles, told us how the soul of a fop might be in

and act from the top or possibly the gloss of his beaver hat or the swinging and knocking of his nobby cane. The flapper, I suppose, by the same token might act from the center or base of her flying and rattling galoshes. To-day the self, when serious and alert, when consciously and actively and responsibly its own real contemporary, is confined to the reach, not of some girl's expansive footwear or some foppish man's tall hat or swinging cane, but of controlled electricity.

X

Technology, including artifacture—instead of manufacture—to the point of a highly developed automatic machinery was, as will be recalled, the second of the specially selected signs of our time of day. Discussion of this may be brief, since what has already been said of the first, anthropology and psychology, of their physical scientific "close-up" of man, and of the whole world by the remarkable control of electricity brought sensuously close to a coincidently expanded individual, can not but help greatly to the understanding of the second, technology. Anthropology and technology are indeed closely related. They are to each other very much as an organism to its habitat or, better, as conscious humanity to the more or less external instruments by which human life is provided with a free medium.

Thus it has become clear to us that in a real sense we are to-day conscious, that we experience what we do experience, not immediately and with unaided senses or faculties generally, but very often and very normally for our time mediately and even vicariously. Either we ourselves are really expanded in the way suggested already or—as only another and significant way of getting at the same truth—our experience is nowadays in large measure had or conducted for us. Not only is much of our seeing and hearing as well as much even of our thinking—remember, for simple example, the computing machines in our business offices and the newspapers, alas more often partisan than accurate—done for us, but also, to come to the matter of our present interest, in this age of technology the very labor of life, effecting this, producing that, is being taken off our human shoulders. In other words, ours is an age of almost self-running and strangely intelligent machinery. A well-nigh objective or external, automatic, vicarious artifacture is rapidly supplanting direct and humanly taxing and costly labor and manufacture. In war, too, as in peace, mere direct man-power is meaning less every day, while a more productive or more destructive power has been taking its place. One's little finger touching a button or a lever and to do so needing an intelligence only commensurate with it may start machinery that will effect in a short time

results which not long ago in our history required hundreds of men, working for days and weeks with long hours and wearing and wasting hardships and in the end producing what in quality and quantity was not as serviceable or efficient. Yes, our era of anthropology with its world-broad realism is also coincidently and consistently an era of technology and a world-supplying productivity. Our mediated and vicarious consciousness and our mediated and vicarious labor simply belong together.

About two centuries ago there was an interesting Frenchman[3] who ventured to write of the possibility of an animated statue. How seriously he wished to be taken it is hard to say. But to-day, far outrunning his speculation, we have had fabricated for us and already engaged in doing much of our work a wonderfully intelligent automaton. The Iron Man,[4] he is being called by some, or the Great Automaton, the Vicarious Army or the Modern Giant. He is, of course, no mere dumbwaiter or curate's assistant or Lazy Susan. He is, all in one, an unnumbered host of such useful creatures and a great deal more and his service is not just here and there personal or domestic but generally social and even syndicated. "Intelligent," I called him. It is, in fact, he who sees and thinks for us in all those ways of our vicarious consciousness from the thermometer to the wireless as well as works for us. Children of the future will suffer no lack of stories about a wonderful giant; a cruel giant perhaps; perhaps, properly approached, a very friendly one.

I may not and need not tell the story of his gradual fabrication or—as better to say—of his growing up to his present maturity and power. It would be only the story of Christendom in one more way, quite parallel to what has been told here already. Yet this I will say. It is but the story of a low efficiency through direct and always costly exploitation and mobilization of human creatures in an army or rigid institutional personnel or mechanically organized group or gang of any sort giving way to the mechanically far more productive and humanly far less costly efficiency through aid of the Modern Giant. In it all, too, nothing can have more interest than the striking fact that only as man has clearly found himself in the natural world, abandoning his one-time aloofness and submitting himself to the observations and close exposures of natural science, has he gained the ready service of the Giant Automaton and, whatever be in store for the future, had his already notable immunity from the direct exploitation of earlier times. Otherwise put, it would seem to be no mere accident that at the same time the human person has become an object of intimate science and the

[3] Buffon, 1707–88.

[4] See "The Iron Man of Industry," by Arthur C. Pound, Boston, 1922.

Giant Automaton has been fabricated and set to work. May it be that the liberation through the latter has really removed the hardship and loss that some have fancied in the former? Those to whom science and its materialism have meant only the complete undoing of man, making him mere creature of matter, should pause to observe and reflect. Behold the Giant Automaton, truly an irrefutable witness to what they would think, the very creature of matter which they imagine—except, of course, for his size and power. By his size and power he is no "mere creature." But reflect that he is not man after all. In fact by him from what he is, automatism and all, man himself is freed! Accordingly, save among those who insist on looking at one thing but seeing another, his real testimony just by virtue of his vicarious instrumentation of life is that matter and machinery are for man, not man merely for or of them.

In any case the term, physical, really is appearing to be like those guttural names, Gottesliebe and Himmelhoch, only harsh in sound; when understood, by no means so in meaning. The day's materialistic and naturalistic realism is actually inaugurating a new era for the human spirit. Alive, as we have found it, with the nobly purposed but now broadened and deepened and so greatly spiritualized traditions of the past, bringing man and nature intimately close but at the same time either expanding man to a world-reach or so contracting the world as to make it all near and real to man, and freeing man through automatic machinery set to his service from exploitation, it ought possibly to go under another name. For a fact, did Spirit ever have the door of idealistic opportunity more widely opened?

XI

There was to be considered, finally, a third sign of our time: anthropology, technology, adventure; the third, adventure, like all true adventure, bringing no mere expansion of what has been, no mere accumulation in kind, but a different quality of life and a new valuation, say a new humanism.

Perhaps from what has been said the reader has already felt adventure as present or as soon coming. Possibly his own experience of life to-day has been as of a charged atmosphere suggesting adventure not without danger. Still, to appreciate the adventure, the possible new opportunity now opened to mankind, do but consider, to begin with, how general the recent actual or at least now wholly possible benefit of life is, some of course enjoying much, others having only some of the new leisure, and then reflect how very different must be the quality of the new life thus made possible. In some degree a leisured democracy instead of just a

leisured class is promised. Thanks to machinery, everybody may expect more time off, "shorter hours"; but, aside from such liberation and leisure, there may be expected a certain leisure in active life, not just from it, as we get more used to the efficiency, to the automatism and to what some call our present speed. The old instrumentation of life, directly dependent on man-power and in its movement fatiguing and exhausting for man when not also destroying, has inspired, even among those who were personally involved in it, poetry, art, philosophy, human reflection and appreciation generally, but to-day the new vicarious instrumentation of life is only just beginning to be taken in a spirit sufficiently leisurely for such reflection and the intimate human expression always proceeding from reflection. In some degree, however, a leisured democracy already belongs to the day's adventure; in some degree our day's active life is also getting more leisurely and reflective; and, life itself being so different, a new valuation of life, accordingly, with all that this implies, may be or must be near at hand.

Riding in an automobile, whether as driver or as passenger, is certainly experience of a different quality from riding behind animals that can grow weary or from being carried, with literal meaning now or in metaphor, by one's own fellow-beings whose fatigue and subordination one can not help feeling. In general, too, leisure or leisureliness through automatic machinery and standard impersonal and objective systems must be very different in its quality from leisure, necessarily much more limited to the few, by direct human service. The Giant Automaton can not grow weary; at the same time his efficiency is very great; and with the new freedom which he brings a new valuation, as was said, a new and deeper humanism, would seem inevitable.[5]

Accordingly, while not disposed to hail novelty loudly or recklessly, while recognizing the danger of seeming to advocate or preach it, I can still understand sympathetically the day's groping for novelty in art, literature, morals, religion, in all the humanities, in economics also and in politics, as only so much natural adventuring to meet the day's demand for new values. So much of life has become automatic. We have bottled and tinned and canned not merely our foods but in subtle and sensitive machinery our labor and to a startling extent our very culture, our music, our drama. These are all provided for us vicariously. Small wonder that our human spirit between hope and fear, real freedom and a license as dangerous as at times it has seemed even unbalanced, is reacting aggressively to the challenge, bent on adventures in humanism.

[5] In an essay, Ages of Leisure, one of several essays recently published under the general title of Leadership and Progress (Boston, 1922), I have discussed this subject at greater length.

Consider, furthermore, how remarkably and how quietly science has wrought. Small wonder the atmosphere seems charged. We are to-day, probably without clearly realizing it, members or subjects of a régime, most deftly elaborated by science in all the varied ways of its interest and activity. The dynamic possibilities of this no one of us can measure. Our widespread industrialism, as we hear it called, has cared relatively little for the laws of state, a great deal for those of physical nature. Is there now any important industry without its laboratories, its experiment stations, its support of scientific research, its high-salaried scientific workers? Such devotion to science, then, and to its applications, not indeed confined to industry but conspicuous there, has effected a remarkable régime, a great organization, and of course organization always means mobilization of the latest available forces and resources. To-day, moreover, the mobilization already effected or now promised can hardly be overstated. In history from as many years before Christ as you please down through the centuries we read of invading hosts. In our very recent times we often have had counted for us the vast population of one region of the earth or another and have been warned in conclusion against this colored peril or that and its irresistible numerical power. It may be that history-making must still go on in that way. The spots of the leopard may be quite unchangeable. But the power in the régime already inaugurated by science is at least no power by mere populations and enjoyment of its benefits may not depend on mere physical man-power or numbers. As part of our day's adventure, then, is the chance of supplanting the old power with the new and of so developing the new as to set the nations or the races, whatever their populations and available fighters, on a basis of equality with respect to the old and so secure against its attacks.

Political scientists might say of science's régime with the new power which it is mobilizing and the worldwide reach of its various instruments that it is at present rather *de facto* than *de jure*; that is, quite actual but still unofficial. So it is and its full inauguration and development only wait on official recognition. It needs, in other words, to be idealized and to be made purposive and church as well as state is now being asked to recognize it. Will the state respond? Will the state recognize the world-domain of the new régime, the world-reach of the new power, the ecumenical realism of the life of to-day? Not in so far as any state, like our own, continues to feel or at least to cry "Isolation!" when *de facto* there is no isolation. Will the church give its sanction? Not in so far as any church, Presbyterian or Episcopalian or what you will, continues to betray its Christian origin by still asserting some narrow orthodoxy or fundamentalism or a mo-

narchical and supernatural theism, when the expansiveness of God has long left such things behind? For a time the two, both state and church, by their inertia may defy the new régime and its broad and essential theocracy, but the fact remains that man and nature have been brought sensuously and realistically close, the world has been made intimate and small, and man depends too much on memory not still to insist on spiritual values and new opportunities. The small-town statesmanship or churchmanship of some of our so-called contemporaries, who would still think of the conduct of the world and its affairs as if no one's view could extend beyond the top of the first mountain range or more than three miles out to sea or beyond the letter of a fourth century creed and who by their more obstinate than honest conservatism are inviting disastrous violence rather than real and constructive progress, may well remind us of that man whose car was wrecked because, forgetting that old Dobbin was not still in the shafts, he neglected the necessary long view of the road. The *de facto* régime must be consciously recognized, idealized and made *de jure*.

XII

I know well that this which I have been calling the régime, the *de facto* régime, set up by science, has often been in disfavor among others besides the conservative theologians and politicians. So many have seen only the dead machinery and the materialism of it and have no sense of the wealth of meaning and ideal value in it. In book after book, in essay after essay, great alarm has been expressed over the wide and blighting rule of machinery.[6] Some have even proposed that we give it all up, call science and its gift of the new power a failure or a disaster, and ere it be too late get back once more to the simple horse-and-buggy life of the good old times. And why not? Or why stop even there? I can reply only that those remonstrants seeming to prefer for a slogan "Back to nature!" instead of "On with nature!" ought to read their Bibles, if they can find them. Scripturally as well as morally and in broad sense biologically it is proper to use for possible return the talents one has, not to neglect them. We are told that modern machinery is killing individuality, destroying the fine qualities of personal interest and initiative, whereas, as I have to believe, it is making possible such adventures in individuality or personality as the world has not yet known. Remember how we have found most intimately associated with the growth of the Great Automaton a noteworthy distribution of leisure or in work itself the possibility of a new and reflective leisureliness. Remember how out of these may come, as was suggested, a new humanism with new depths of inner

[6] See, for example, "Social Decay and Degeneration," by R. A. Freeman, Boston, 1921.

life and new reaches of character as well as new outlook and understanding. Our age of machinery, then, ought to challenge the humanities, not discourage them, and develop personality, not kill it. Some there are now, as ever before, who refuse to hear opportunity when it knocks at the door or who take alarm, hearing the knocking, lest they may have to leave their comfortable firesides. Which would they? Have history move forward in spite of their home comfort and inertia or with their active interest and bold cooperation?

But automobiles, they persist, are making the legs of men atrophied; adding-machines are weakening the mind; and, in general, from lack of necessary exercise physical or mental man is getting flabby. Degeneration is already setting in. Moreover, let body and mind go and the soul will follow. *Mens sana in sano corpore.* To which must be added: *Spiritus integer in integri mente.* All quite true and also showing imperfect if not already degenerate thinking. So might one argue from every gain or advance in life. Making the old effort no longer necessary, it is bound to bring laziness and eventual degeneracy! But whence came that old effort? Can we not trust the source of that for new effort now? And under conditions that hold still larger possibilities of gain? Is there not a fable somewhere of a creature who, having been well-fed and at first feeling only the satiation of his meal, exclaimed as he stretched himself for sleep: "Now is all done. I need strive no more." Later, however, and my memory do not fail me, the food assimilated, he was out on the hunt with more strength and more alertness and a wider field than ever before.

XIII

May I now be humored a little? Allow me to court fancy. It is poor thinking, after all, that does not sometimes lapse in this way. East and West! Personality and Power! Only yesterday I was reading with much interest an article[7] by a Chinaman, who had been studying at Columbia University. This was his subject: "Why China has no science." The West has had science; the East not. Why? Character and happiness, says the writer, Yu-lan-Fung, have been the passion of China, of the East generally; power over nature has been the passion of the West. "Westward the course of empire takes its way" is a line of early eighteenth century versification often quoted at least by Americans before the present century. Now, I suppose, the East is getting too near, alarmingly near. Is any distance left between it and the western frontier?

[7] In the *International Journal of Ethics*, 1922, V, xxxii, pp. 237–263.

Personality and power! To-day we are beginning to see that as pursued by East and West these have been only qualified successes, like most half-truths. Is it that each has subordinated and neglected the concern of the other, seeing this only darkly and, as it were, during the night and so irresponsibly? Is it that, figuratively as well as literally, East and West have exchanged day and night, responsibility and irresponsibility? Again and again we hear that in temporal things the East has been very corrupt, according to one report "making the politics and economics of New York or Chicago look like a Sunday School," while in spiritual and intimately personal things the West either has been goody-goody and pharisaical or has cultivated defensive complexes of irresponsibility and environmental determinism.

Allow me, then, to imagine that at this time of Christendom's history, when important adventures in personality are among the adventures now offered, the Eastern question, whether peril or opportunity, may easily prove more than just the economic and political question which in general it has appeared. In India and China, in the East at large, the Western question in its turn is prominent if not dominant. But, to speak as one moving west, technology by its power over nature has at last made the world small, overcoming the curvature; the intimacies of anthropology have made man primarily man and world-wide, only secondarily racial or ethnic and local; and the two may end by making East and West, West and East, each with its half-truth, meet the other at least half-way. In other words, once more in history the West may turn to the East for spiritual help. Prophecy and folly look as alike as twins; but there is, to say the least, ground for expecting from the future, not only still undreamed-of powers over nature, but also new depths of character and personal individuality. More character in the West might, perchance, be the best maneuver against the alarms and perils of the colored East.

XIV

For the day, finally, so charged with adventure is this life of ours, all things seem in a great flux. In extraordinary measure nothing that was, state or church, industry or morals, art or science, seems any longer what it was. Reactions settle none of the problems. Mere violence only stimulates and perhaps justifies reaction. Is this? Is that? Is anything any longer? Anything stable and dependable? Familiar feelings these and often spoken questions, reflecting the groping spirit of every department of life. A number of troubled souls, simply exhibiting in religion what is the situation everywhere, got together not long ago somewhere in the maelstrom of New York and after much futile communing

finally sent out to a score of scientists and philosophers over the country a questionnaire with this for their first query: Do you acknowledge the existence of God? And for their second: If you have just answered yes, has your answer been from faith or reason? There could hardly be, at least in these days, more irrelevant and more futile questions than those two. Such questionnaires, by no means confined to matters of religion, are born of a sort of mental and moral inertness, when bold action is what is needed. Nothing ever just exists in a critical time, in a time of transition. To-day, to have what one would one must not just look for it in some pigeonhole or get one's friends together and make them search their pockets or, these devices failing, in desperation send out a lot of yes-or-no questions and so let a vote settle it all. The city fathers of San Francisco once voted that there was no plague in the city! One must, in a critical time, will what one would. Will, not a passive faith nor yet a formal reason, is the primary faculty of adventure. So, I say, merely believe in nothing to-day; also take nothing just from reason; will everything that past experience and present opportunity seem to make worth while. Faith may recall and cherish and suggest; reason is ever an excellent guide, a finder of ways and means; but will ventures and realizes.

And, while there can be obstinacy and inertia, sometimes taken for will, while there can be impulse and its fascinating blindness, taken not infrequently for virtue, there can not be good will or true will, there can be no effective and progressive activity, there can be no virtue where there is no clear sense of the time.

Spirit of the Renaissance! Of the eastward crusades and the westward explorations! Once more bold and pious adventures in naturalism and in humanism, in power and in character! Progressive purpose spiritualized with cherished memory! Man's will awakened and again bent on having what it would! In such phrases I would sum up our time of day and its challenge. But every one should keep in mind that the world to be awakened to-day is the world of to-day as anthropology and technology have been making it, and making it real, not that of five centuries or more ago as the medieval régime had instituted it. Should be remembered, too, that to-day's adventures in naturalism and humanism are still, like Christian's of those earlier days, such as can attain nothing worth while without possible disaster always attending. Reality is still, as then, like gold.

"Then I saw that there was a way to Hell, even from the Gates of Heaven."

THE PSYCHOLOGICAL BASIS OF DEMOCRACY

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If one desires to work with a material substance of any sort, he does not hark back to alchemy for his method of procedure, but he quickly brings to his aid that most painstaking science called chemistry or that of physics. If one seeks to solve a problem of mind scientifically, he calls for no ghost of the past or present. He does not play around the door of that charlatan, the "sub-conscious," nor does he seek anything bizarre, but just science. He recognizes that science is really what it claims to be and may not sit in the corner with mysticism and superstition and still be science. He realizes that there is a sisterhood of the sciences and that they work in harmony; that psychology must not be regarded as the ghost that walks in the laboratory of natural science but must be actually a part of our great scientific system.

This being so, then society may come to psychology for assistance in the solution of her problems. In this case let us take the problem of the Psychological Basis of Democracy. When one remembers what James had to say of the evanescence of the "will" as the expectant seeker approaches the psychological cupboard, he is seized with fears that he will find it bare or only meagerly supplied. Upon looking into the inventory he discovers nothing labelled "Democracy." He only finds a set of reflexes, instinctive behavior, tendencies, pure and derived, learned acts spun out of these, preparatory reactions, consciousness in forms of sensation, memory, imagination, recognition, physical and mental trial-and-error, etc. Almost sick at heart he may start to turn away, until he remembers that human life is a synthesis of all these and that, moreover, this is our inventory of all scientific psychology; and if the psychological basis of democracy is to be found anywhere, it is to be found just here.

He makes now a more critical examination of the problem, perhaps, and notes that the term democracy is a term of social import. It indicates the activity of many human beings. But this helps little, for the psychology of the group is the psychology of the individual mind as found in groups under certain conditions. We must seek that form of behavior of the individual that occurs in a democratic situation.

The question now is: How does the individual behave in a situation called "democratic" that would differ from one that is not "democratic"—a non-social situation if such will be singled out just here? We perhaps may safely say that all democratic situations are problem situations. This inference leads the way to the solution of the very problem we are trying to solve. For we quickly ask ourselves, "By what method can the individual solve his problem?" Dynamic psychology is prompt to answer, "By the trial-and-error method." Trial-and-error is a term to conjure with in educational and psychological circles, but the method has a history that goes beyond the time when it was first singled out by Professor Edward L. Thorndike as the one by which an animal learns. Folk sayings couched the method in various vulgar forms of expression such as: "If at first you don't succeed, try, try again," getting a thing done by "hook or crook," "going at it by main strength and awkwardness." As intimated, it came into respectability from its humble folk origin through the door of the laboratory of the animal psychologist. Then later was noted the trial-and-error character of the learning of chicks to drink and to pick up their food (Morgan), of cats and chickens to escape from cages of imprisonment to food on the outside by means of learning to raise latches and pull strings (Thorndike), of earthworms to withdraw from the irritating stimulation of light rays (Yerkes), and of white rats to open cages and run mazes (Watson). In fact, the method stood out so prominently in the animal laboratory that human psychologists soon took the cue and by means of laboratory studies on human beings announced their conviction that human learning was fashioned after the same method, *i.e.*, trial-and-error. Human subjects were observed in their method of learning the solution of common mechanical puzzles (Ruger), learning to send and receive telegraphic messages (Bryan and Harter), to do typewriting by the touch method (Book), to toss balls (Swift), to run mazes blindfolded (Hicks and Carr). Studies have been made as well of learning a foreign language. What is more, reasoning as well as learning is now said to be merely trial and error with mental elements. Such materials as geometric problems and common folk riddles have been used to demonstrate facts to support this last generalization.

In its ideal and scientifically theoretical form the method may be thus pictured, no feature of which may be omitted: (1) A situation practically new to the learner; (2) a drive within the learner which makes urgent the solving of the problem presented by the situation; (3) features in the situation calling out such native or learned responses as the learner may possess; (4) success and failure in successive trials to meet the situation; (5) elimination of the

failures and persistence of the successes; (6) satisfaction produced by the successful response favoring its fixation in the nervous mechanism, that is, the successful responses become more and more firmly established because of frequency and facilitating tendencies, while on the other hand the wrong responses die out from sheer lack of innervation and from inhibitory tendencies; (7) the learner meeting the situation with speed and accuracy raised to highest indices of efficiency. This is the picture of the method of trial and error, this is the picture of the method of human and animal learning. Can it be the picture of human social as well as individual progress? Before we undertake answering this question, let us present the method working in some erratic form in the individual.

In the first place, the situation must be thought of as new or one to which the individual is not adapted. If the organism is alive, some response will be called forth whether the situation is old or new. If it is old, adaptation is made immediately and satisfaction sets in. But if new, the innate tendency to bring about the end-response persists until some means is found for satisfying the tendency with that satisfying end-response. Then an erratic situation might be (1) one in which the drive would be absent. There can be no trial and error without a drive, *i.e.*, no learning without a tendency. So the individual may fail to learn because of absence of a drive. Again (2) the situation may be all that is desired, likewise the drive may be present, but the responses may be thwarted in one way or another so that their effect on the situation is not felt. Or (3) it may be that all the energy is being absorbed by some wrong though habitual responses, so that some more modest but perhaps more promising one never has an opportunity to make its trial. The fact is this is just the thing that is likely to happen in an experienced being: habits are more vigorous than new forms of behavior and tend to crowd them out. The learner should keep a very careful watch on these old forms of behavior for fear they will throttle the more promising new unestablished forms. (4) On the whole an erratic situation may arise by any factor preventing by intention or accident the free trial and error of the organism in its effort to meet the situation.

In all the above we have meant to bring out the fact that the essential elements of the method of trial and error are: (1) An aroused drive and (2) a free and varied response to features of the situation.

Coming nearer to an answer to our question raised above as to whether social progress comes about by trial and error of a social sort, we may say that we do not ordinarily take the view (but we may safely do so) that the individual organism is a society, as it were—it has its hands and feet, its eyes and ears, its reflexes and

learned processes, its instincts and experiences, and when a situation arises which must be met or the organism must perish, it requires a very free participation of all the factors of the whole man to meet the situation. The eye may not say to the ear in such time of stress, "I have no need of thee;" nor may the hand say to the feet, "I have no need of thee." It may be possible that some modest, insignificant, long-past experience may be just the thing needed for the solution of the problem in hand. In fact, it would be foolhardy for the organism to allow the "tying up" of the hand so that it might not participate in the free trial-and-error process, for it might be just the instrument needed. And even though so much of the organic colony remain inactive because of the fact that it is not needed for overt action, still, though inactive, there must be a sympathetic coordination of all of it. There is a sort of participation by the apparently inactive parts. The right hand always knows what the left is doing by sympathy. We will call this *coordinated trial-and-error of the individual organism,* and it is free and whole-hearted as long as all members are earnestly participating. This is the method of democracy of the individual organism.

In order to answer the question as to the psychological nature of the method of democracy, we ask the further question, By what magic has the psychology of the individual changed when we regard him as a unit in a social group? To be sure, his learning of responses looking to social adaptation is characterized by trial and error. Social progress means the adaptation of the individuals of the group to their natural environment and to each other. The question is still a problem of the individual organism in learning how to meet a situation, though he is a unit in a group, a link in a chain. "No chain is stronger than its weakest link"; a group is strong or weak as its units are strong or weak. A social group is never really static. Always playing on the individuals composing it are the features of a present situation, and this situation is new, one to which the group is not adapted, even though its features arise within itself as individuals influencing one another. The individual drives come into play. Here is action and interaction as the social trial and error proceeds. And the learning is genuine for the individual and the group as the individuals participate freely in it. Tendencies aroused in the individual seek their end-responses and persist until they do really find them. Satisfactory adjustment of the group means satisfactory adjustment of the individuals composing the group, and the trial and error continues as this point is approximately attained. New situations arouse dormant tendencies which function for further learning or progress. As the method of learning for the individual is free, unhampered trial and error, of

the individual's repertoire of native and acquired reactions upon the situation, so is the method of democracy the free, unhampered trial and error of its individuals acting in groups.

Old social forms of adaptation fall away with changed situations, and as new tendencies begin to function a reformation sets in because of a renaissance. A renaissance arises because of the discovery of old manuscripts. A medieval mind awakens from darkness of superstition by the shifting from the tendency of fear to that of enjoyment of life. A social revolution occurs when the tyranny of rulers is apparent to those being ruled. Industrial hands and feet become restless when they suspect injustice on the part of the overlord. Orthodoxies, sufficient unto the day, until a new slant is gotten on God and the universe, crumble away when the individual minds begin to question.

Social learning or progress is hampered as long as (1) the situation remains unchanged, whether natural or social, (2) the individuals fail to feel the drive, (3) the individuals do not freely respond because of indifference or compulsion to inaction. Cocksureness is represented by activity on the part of isolated members of the group who deliberately prevent the free action of others, however humble, which, of course, is contrary to the principles of learning, and also makes impossible coordination of all parts. Restricted activity, whether it be caused by an absolute monarch or a benevolent despot, is still a case of limited response of the individual and so of hindered development of the individual and consequently of the group.

Well-meant clerical officiousness is no exception and might well hang a millstone about its neck rather than delimit the intelligent trial and error of its individual parishioners.

The case seems clear. The ideal of democracy is free trial and error, since the procedures are one and the same method. For the case of social activity, we have trial and error in which all the individuals of the group participate. If some members of the group are prevented from participating by being compulsorily isolated, the group suffers, and so likewise if some members are inactive because of indifference. It makes no difference as to the cause of the inactivity. If some members of the group should undertake to solve all or a few of the problems in the absence of some of the members, they may be guilty of cocksureness, which has hindered the solving of many a problem of the single individual.

To summarize, this, then, is the psychological basis, the psychological method of democracy; *i.e.*, absolutely free trial and error of the members of the group all sincerely looking to the solution of some social problem. Social trial and error may be hindered

in one way only, in which case it actually ceases to be the trial-and-error method, and that is when only one part of the group undertakes to handle the situation and the remaining part is inactive. In individual psychology—and it is just as true in social psychology as we understand it—the latter situation may arise in two ways: Indifference involving the inactive part and enforced inactivity likewise involving that part—both of which prevent the free trial and error of all parts, and there is no trial-and-error process after all if it be not of a whole-hearted nature. *Cocksureness* is an illustration of restricted activity. It is a case of one's gratuitously assuming that he knows how to meet the situation, when in fact he has little right to make such an assumption. It is a mark of a low intelligence in the individual whenever this attitude characterizes all one's voluntary acts, and one is intelligent to that degree in which he becomes "as a little child," as it were, getting down on the humble level of trial and error when the situation demands it.

Finally, it may be well to ask if there are any really democratic situations of this free trial-and-error sort where all members actually are engaged in the solution of some social problem. It would be an ideal situation if there were. But we have no real democracy as a purely psychological process in this sense. The effort will be ever to strive to approach it and always to stimulate all members to earnest and intelligent participation in the free trial-and-error activity for the solution of social problems.

SOME BEARINGS OF ZOOLOGY ON HUMAN WELFARE[1]

By Professor J. H. ASHWORTH

THE bearings of zoology on human welfare—as illustrated by the relation of insects, protozoa and helminthes to the spread or causation of disease in man—have become increasingly evident in these later years and are familiar to every student of zoology or of medicine. At the time of our last meeting in Liverpool, insects were suspected of acting as transmitters of certain pathogenic organisms to man, but these cases were few and in no single instance had the life-cycle of the organism been worked out and the mode of its transmission from insect to man ascertained. The late Sir Patrick Manson, working in Amoy, had shown (1878) that the larvae of *Filaria bancrofti* undergo growth and metamorphosis in mosquitoes, but the mode of transference of the metamorphosed larvae was not determined until 1900. Nearly two years after our last meeting here the part played by the mosquito as host and transmittor of the parasite of malaria was made known by Ross. In addition to these two cases at least eight important examples can now be cited of arthropods proved to act as carriers of pathogenic organisms to man—*e. g.* Stegomyia—yellow fever, Phlebotomus—sandfly fever, tsetse-flies—sleeping sickness, Conorhinus—South American trypanosomiasis (Chagas' Disease), Chrysops—*Filaria* (*Loa*) *loa*, the flea *Xenopsylla cheopis*—plague, the body-louse—trench fever, relapsing fever and typhus, and the tick Ornithodorus—African relapsing fever. In selecting examples for brief consideration I propose to deal very shortly with malaria, although it is the most important of the insect-carried diseases, because the essential relations between the Anopheles mosquito and the parasite are known to every one here. There still remain lacunae in our knowledge of the malarial organisms. Ross and Thomson (1910), working in this city, showed that asexual forms of the parasite tend to persist in small numbers between relapses, and suggested that infection is maintained by these asexual stages. Such explanation elucidates those cases in which relapses occur after short intervals, but the recurrence of the attacks of fever after long intervals can only be explained by assuming that the parasites lie dormant in the body—and we know neither in what part of the body nor in what stage or

[1] From the address of the president of the Section of Zoology of the British Association for the Advancement of Science. Liverpool, 1923.

condition they persist. Nevertheless, the cardinal points about the organism are established, and preventive measures and methods of attack based on a knowledge of the habits and bionomics of Anopheles have been fruitful in beneficial results in many parts of the world.

If we desire an illustration of the vast difference to human well-being between knowing and not knowing how a disease-germ is transmitted to man, we may turn to the case of yellow fever. When this pestilence came from the unknown, and no one knew how to check it, its appearance in a community gave rise to extreme despair and in many cases was the signal for wholesale migration of those inhabitants who could leave the place. But with the discovery that Stegomyia was the transmitting agent all this was changed. The municipality or district took steps to organize its preventive defences against a now tangible enemy, and the successful issue of these efforts, with the consequent great saving of life and reduction of human suffering in the Southern United States, in Panama, in Havana and in other places, is common knowledge. It is a striking fact that during 1922 Central America, the West Indies, and all but one country of South America were free from yellow fever, which has ravaged these regions for nearly two centuries. The campaign against Stegomyia is resulting, as a recent Rockefeller report points out, in yellow fever being restricted to rapidly diminishing, isolated areas, and this disease seems to be one which by persistent effort can be brought completely under control.

In 1895 Bruce went to Zululand to investigate the tsetse-fly disease which had made large tracts of Africa uninhabitable for stock, and near the end of the same year he issued his preliminary report in which he showed that the disease was not caused by some poison elaborated by the fly—as had been formerly believed—but was due to a minute flagellate organism, a trypanosome, conveyed from affected to healthy animals by a tsetse-fly (*Glossina morsitans*). In 1901 Forde noticed an active organism in the blood of an Englishman in Gambia suffering from irregularly intermittent fever, and Dutton (1902) recognized it as a trypanosome, which he named *Trypanosoma gambiense*. In 1902 Castellani found trypanosomes in the blood and cerebro-spinal fluid of natives with sleeping sickness in Uganda, and suggested that the trypanosome was the causal organism of the disease. The Sleeping Sickness Commission (Bruce and his colleagues) confirmed this view, and showed that a tsetse-fly, *Glossina palpalis*, was the transmitter. Since then much has been learned regarding the multiplication of the trypanosome in the fly and its transference to man. For some years this was believed to take place by the direct method, but in 1908 Kleine demon-

strated "cyclical" transmission, and this was shown later to be the principal means of transference of *T. gambiense.* In 1910 Stephens and Fantham described from an Englishman, who had become infected in Rhodesia, a trypanosome which, from its morphological characters and greater virulence, they regarded as a new species, *T. rhodesiense,* and its "cyclical" transmission by *Glossina morsitans* was proved by Kinghorn and Yorke. Recent reports by Duke and Swynnerton (1923) of investigations in Tanganyika Territory suggest that direct rather than cyclical transmission by a new species of Glossina is there mainly responsible for the spread of a trypanosome of the *rhodesiense* type. The impossibility of distinguishing by their morphology what are considered to be different species of trypanosomes, and the difficulty of attacking the fly, are handicaps to progress in the campaign against sleeping sickness, which presents some of the most subtle problems in present day entomology and protozoology. Here also we come upon perplexing conditions due apparently to the different virulence of separate strains of the same species of trypanosome and the varying tolerance of individual hosts—on which subjects much further work is required.

The relation of fleas to plague provides one of the best and most recent illustrations of the necessity for careful work on the systematics and on the structure and bionomics of insects concerned in carrying pathogenic organisms. Plague was introduced into Bombay in autumn 1896, and during the next two years extended over the greater part of Bombay Presidency and was carried to distant provinces. The Indian Government requested that a Commission should be sent out to investigate the conditions. This Commission, which visited India in 1898–99, came to the conclusion (1901) that rats spread plague and that infection of man took place through the skin, but—and this is amazing to us at the present day—"that suctorial insects do not come under consideration in connection with the spread of plague." Further observations, however, soon showed this conclusion to be erroneous. Liston found in Bombay in 1903 that the common rat-flea was *Pulex* (*Xenopsylla*) *cheopis,* that it was present in houses in which rats had died of plague and in which some of the residents had become infected, that the plague-bacillus could multiply in the stomach of this flea, and that the flea would—in the absence of its usual host—attack man. These observations pointed to the importance of this flea in the dissemination of plague, and the Second Plague Commission, which was appointed and began work in 1905, definitely proved that *Xenopsylla cheopis* is the transmitter of the plague-organism from rat to rat and from rat to man. The mechanism of transmission of the plague-bacillus

was worked out by Bacot and Martin in 1913. They showed that in a proportion of these fleas fed on the blood of septicaemic mice the plague-bacilli multiply in the proventriculus—which is provided with chitinous processes that act as a valve to prevent regurgitation of the blood from the stomach—and a mass of bacilli is formed which blocks the proventriculus and may extend forward into the esophagus. Fleas in this condition are not prevented from sucking blood because the pharynx is the suctorial organ, but their attempts to obtain blood result only in distending the esophagus. The blood drawn into the esophagus is repeatedly forced backwards into contact with the mass of plague-bacilli and on the sucking action ceasing some of this infected blood is expelled into the wound. The transmission of plague depends on the peculiar structure of the proventriculus of the flea and on the extent to which, in certain examples, the plague-bacilli multiply in the proventriculus. Such "blocked" fleas being unable to take blood into the stomach are in a starved condition, and make repeated attempts to feed, and hence are particularly dangerous.

Until 1913 it was believed that all the fleas of the genus Xenopsylla found on rats in India belonged to one species—*cheopis*, but in that year L. F. Hirst reported that the rat-flea of Colombo was *X. astia*, which had been taken off rats in Rangoon, and described by N. C. Rothschild in 1911. Hirst ascertained that this flea did not readily bite man if the temperature were above 80°F. A collection of 788 fleas from Madras City proved to consist entirely of *X. astia*, and Hirst suggested that the explanation of the immunity of Madras and Colombo from plague was the relative inefficiency of *X. astia* as a transmitter. Cragg's examination (1921, 1923) of 23,657 fleas obtained from rats in all parts of India shows that they include three species of Xenopsylla—namely, *cheopis*, *astia*, and *brasiliensis*. This last species is common in the central and northern uplands of peninsular India, but its bionomics have not yet been investigated. *Cheopis* is the predominant species in the plague areas, while *astia* is the common flea in those areas which have remained free from plague or have suffered only lightly. In Madras City, for instance, during the twenty-one years, 1897–1917, plague has occurred in twenty of these years, but the average mortality was only .013 per thousand—that is, though the infection has been repeatedly introduced there, it failed each time to set up an epidemic. The significance of an imported case of plague depends in large measure on the local species of Xenopsylla. Hirst has made numerous attempts during the plague season in Colombo to transmit plague by means of *X. astia* from rat to rat, but with negative results, and *X. astia* was never found to behave like a "blocked" *cheopis*.

The distinction of *X. cheopis* from *X. astia* is not an entomological refinement with purely systematic significance, but corresponds with a different relation of the species to the epidemiology of plague, and hence becomes a factor of great practical importance. If through these researches it has become possible by examination of the rat-fleas of a locality to estimate accurately its liability to plague, anti-plague measures may henceforward be restricted to those areas in which plague is likely to occur, *i.e.*, where *cheopis* is the predominant flea. Thus, a great economy of effort and of expenditure and a higher degree of efficiency may be achieved; in fact, the problem of the prevention or reduction of plague may be brought from unwieldy to practicable proportions. When it is remembered that since we last met in Liverpool some ten and a quarter millions of people have died in India from plague we have a more than sufficient index of the importance of a precise knowledge of the systematics, structure and bionomics of the insect-carrier of *Bacillus pestis.*

Another of the outstanding features of the period under review has been the extensive and intensive study of the Protozoa. The structure and the bionomics and life-history of these organisms have been investigated with the help of the finest developments of modern technique. It is fitting here to record our acknowledgment to two staining methods—Heidenhain's iron-haematoxylin and the Romanowsky stain (including Giemsa's and Leishman's modifications), which have added greatly to our technical resources.

There is time to refer only to certain of the Protozoa which directly affect man. Twenty years ago our knowledge of the few species of Protozoa recorded from the human alimentary canal was defective in two important respects—the systematic characters and the biology of the species—so there was much confusion. Subsequent investigations, and especially those of the last ten years (by Wenyon, Dobell and others), have cleared up most of the doubtful points, but owing to the difficulties of size and the paucity of characters available it is by no means easy in practise to distinguish certain of the species. Of the seventeen species now known to occur in the intestine of man *Entamoeba histolytica* has received particular attention. This organism lives as a tissue parasite in the wall of the large intestine, where, as a rule, the damage caused is counterbalanced by the host's regenerative processes. But when the destruction outstrips the regeneration intestinal disturbance results, leading to the condition known as amoebic dysentery. The specific characters and the processes of reproduction and encystment of *E. histolytica* are now well ascertained, and it is realized that in the majority of cases the host is healthy, acting as a "car-

rier'' dangerous to himself, for he may develop into a case of acute dysentery, and to the community—for he is passing in his feces the encysted stage which is capable of infecting other persons. Whether an infected person will suffer from dysentery or act as a healthy ''carrier'' apparently depends upon his own susceptibility rather than on any difference in the virulence of different strains of the Entamoeba.

In all work with human Entamoebae there is need for critical determination of the species, for, in addition to *E. histolytica,* a closely similar species, *E. coli,* is a common inhabitant of the intestine. This, however, is a harmless commensal, feeding on bacteria and fragments derived from the host's food. The distinction between the two species rests chiefly upon the characters of the nuclei and of the mature cyst—quadrinucleate in *histolytica* and octonucleate in *coli*—and considerable care and technical skill are requisite in many cases before a diagnosis can be given. And yet this distinction is definitely necessary in practice, for indiscriminate treatment of persons with Entamoeba is indefensible; treatment is only for those with *histolytica*; it is useless for those with *coli,* and subjects them needlessly to an unpleasant experience.

A notable result of recent work is the proof that the more common intestinal Protozoa, formerly believed to be restricted to warmer countries, occur indigenously in Britain. This was first established by a group of observers in this city, and has been confirmed and extended by subsequent workers. There is good reason for believing that in this country the incidence of infection with *E. histolytica* is about 7 to 10 per cent., and with *E. coli* about five times as great (Dobell).

The discovery (1903) of Leishmania, the organism of kala azar and of oriental sore, added another to the list of important human pathogenic Protozoa, but the mode of transmission of this flagellate has not yet been proved.

Of the problems presented by the parasitic worms the most momentous are those associated with Ancylostoma and its near relative Necator, which are prevalent in countries lying between 36°N. and 30°S.—a zone which contains more than half the population of the earth. Heavy infection with Ancylostoma or with Necator produces severe anaemia, and reduces the host's physical and mental efficiency to a serious degree. Until 1898 there was no suggestion that infection was acquired in any other way than by the mouth, but in that year Looss published his first communication on the entry of the larvae of Ancylostoma through the skin, and in 1903 gave an account of further experiments which proved that dermal infection resulted in the presence of worms in the intestine.

At the meeting of this association in Cambridge in 1904 Looss demonstrated to a small company his microscopical preparations showing the path of migration of the larvae. His investigations served to establish the importance of the skin as the chief portal of entry of Ancylostoma, and pointed the way to effective methods of prevention against infection.

Another notable advance in helminthology is the working out of the life-cycle of Schistosoma (Bilharzia)—a genus of trematode worms causing much suffering in Egypt and elsewhere in Africa, as well as in Japan and other parts of the world. These worms when mature live in pairs, a male and female, in the veins of the lower part of the abdomen, especially in the wall of the bladder and of the rectum. The eggs, laid in large numbers by the female worm, provoke inflammatory changes, and cause rupture of the veins of the organs invaded. Until about ten years ago the life-history of Schistosoma had been traced only as far as the hatching of the ciliated larva or miracidium which takes place shortly after the egg reaches water, but it was then shown that this larva is not, as had been held by Looss, the stage which infects man. Miyairi and Suzuki (1913) found that the miracidium of *Schistosoma japonicum* entered a fresh-water snail which acted as the intermediate host, and Leiper and Atkinson (1915) confirmed and extended this observation, and showed that the miracidia develop into sporocysts in which cercariae are formed. We owe chiefly to Leiper's work (1915–1916) our knowledge of the life-history and method of entry into man of the Egyptian species of Schistosoma. He demonstrated that two species of this parasite occur in Egypt, and established that the miracidia develop in different intermediate hosts: those of *S. mansoni* enter Planorbis, while those of *S. haematobium* penetrate into Bullinus—the molluscs being abundant in the irrigation canals. The sporocysts produce cercariae, which escape from the snails and gather near the surface of the water, and experiments with young mice and rats showed that the cercariae attach themselves to the skin, enter and reach the portal system from which they travel to the veins of the lower part of the abdomen. Infection of man takes place chiefly through the skin when bathing or washing in water containing the cercariae, though infection may also occur through drinking such water. And so, at last, these worms which have troubled Egypt for at least thirty centuries have become known in all their stages, and measures for preventing infection—which were of great use during the war—have been devised, and curative treatment introduced.

Other recent helminthological researches deserve consideration did time permit, for there has been much excellent work on the life-history of the liver-flukes and lung-flukes of man, and the life-cycle

of the tape-worm, *Dibothriocephalus latus,* was worked out in 1916–1917. Mention should also be made of Stewart's investigations (1916–19) on the life-history of the large round-worm *Ascaris lumbricoides,* during which he made the important discovery that the larvae on hatching in the intestine penetrate into the wall and are carried in the blood to the liver, and thence through the heart to the lungs, where they escape from the blood-vessels, causing injury to the lungs. The larvae, now about ten times their original size, migrate by way of the trachea and pharynx to the intestine, where they grow to maturity. During last year Dr. and Mrs. Connal have worked out the life-history of *Filaria* (*Loa*) *loa* in two species of the Tabanid fly, Chrysops, and investigations on other Filarias have thrown light on their structure, but there is still need for further researches on the conditions governing the remarkable periodicity exhibited by the larvae of some species (*e.g., F. bancrofti;* in some parts of the world the larvae of this species are, however, non-periodic). The period under review has obviously been one of great activity in research on helminthes, and fertile in measures tending to reduce the risks of infection.

Insects, protozoa and helminthes not only inflict direct injury on man; they also diminish his material welfare by impairing the health or causing the death of his horses, cattle and sheep, by destroying food crops during growth and, in the case of insects, by devouring the harvested grain. The measure of control which man can gain over insects, ticks and endoparasitic organisms will determine largely the extent to which he can use and develop the natural resources of the rich tropical and sub-tropical zone of the earth.

Other applications of zoology to human well-being can not be dealt with owing to lack of time, but mention should be made of two—the researches on sea-fisheries problems which have formed an important branch of the zoological work of this country for forty years, and the studies on genetics which made possible an explanation of the mode of inheritance of a peculiar blood-group, and of some of the defects (*e.g.,* color-blindness and haemophilia) and malformations which appear in the human race.

The rapid expansion of zoology has brought in its train the difficulty of maintaining the connection between its different branches. There is not only the mental divergence of the different workers, due to the necessity for specialized reading, thinking and technique, but also in some cases spatial separation, and this seems to me to be the factor of greater importance. When modern developments of the subject necessitate expansion of the staff and of the working facilities it has not infrequently happened that one of the newer branches of the subject has been placed in another building, and unless careful arrangements are devised the dissociation tends to

become more marked, so that, to take Mr. Bateson's example, the geneticist becomes separated from his colleague whose interests are more largely in systematic zoology, to their mutual disadvantage.

The actively growing physiological branch of zoology will, it is to be hoped, remain an integral part of our subject; for while there are close and friendly relations between the Department of Zoology and the Department of Physiology, the latter is mainly concerned with the training of medical students, and the teaching and research are consequently, in most universities, chiefly directed to the physiology of mammals and of the frog. The medical physiologist can not be expected to prosecute researches on the invertebrates—these are as a rule too far removed from the matters with which he is especially concerned—and yet many of the invertebrates have been found to be especially favorable for the investigation of fundamental problems which the morphologist with physiological leanings and training seems most fitted to undertake. It is a good sign that more students of zoology are including a course of physiology in their curriculum for the science degree, thus preparing themselves for work in comparative morphology and comparative physiology.

The association of zoology with physiology, and with botany through common problems in genetics and in general physiology, is becoming more intimate. The association of zoology with medicine has become of such importance, especially in regard to its parasitological and its physiological aspects, that clearly collaboration with our medical colleagues in teaching and in research should be as close as possible.

Much has been written and said in recent years about the place of zoology in the medical curriculum, and the present seems a favorable opportunity to reconsider the position and to ascertain the general opinion of the body of zoologists on this important matter. There can, I think, be no doubt that the value of zoology taught in its modern significance is being increasingly appreciated by the majority of our medical colleagues. The minority consists of two categories—those who have not taken the trouble to inform themselves of the subjects nowadays brought to the notice of medical students in the course of zoology, and who apparently consider that this is the one subject in the curriculum in which there has been no evolution since they were themselves first-year students thirty or forty years ago, and those who feel that the increasing pressure in the curriculum calls for curtailment of the teaching in what they believe to be the less important subjects. The first of these categories need not detain us, for an opinion based on obsolete data is valueless. Those in the second category merit serious consideration, but I believe even many of these would change their views if

they knew more fully what is being done in the modern course of zoology to give the medical student a broad, scientific outlook. Even if the course on zoology were cut out the time would not be wholly gained for other work, because many of the subjects now dealt with in the course would require consideration in the teaching of anatomy and physiology. The attention of the medical student is nowadays directed in his course of zoology not so much to the study of details of "types" as to the principles which certain chosen animals serve to illustrate. A reasonable knowledge of structure is obviously requisite before the working together of the parts can be understood, and before general principles can be profitably discussed. The student at that early stage of his education must have concrete examples to enable him to grasp the functions of organs, development, ideas as to the relationships of animals, heredity, evolution, and so on, and his work in the laboratory should give him the opportunity of observing for himself the important structural points on which the principles are based. The practical work can not be limited to what the student can do for himself, for at this stage of his training there are many things which he ought to see but which are beyond his technical powers to prepare for himself, so that a good series of demonstration objects is necessary, care being taken that the student not only sees the specimens but appreciates their significance. As the time given to zoology is limited, the examples for study and the principles to be illustrated are to be carefully chosen, for the course in zoology is not only a discipline but should give basal knowledge of value in the subsequent years of study; and, moreover, if the student can see that his zoological work bears on his later studies he will take much more interest in it. It is important, therefore, that the points of contact of his present with his future work should be successively indicated.

The details of the course of zoology for the first-year medical student will vary in the hands of different teachers, and it is well that they should be to some extent elastic. In a minimum course will be included the consideration of two or three protozoa, a coelenterate, an annelid, an arthropod—and especially the features in which it presents advance as compared with the annelid, an elasmobranch fish, and a frog, the primitive features of the fish being emphasized, and the chief systems of organs of both vertebrates compared with each other and with those of a mammal. The functions of the principal organs of all these examples will be dealt with so far as they can be understood from the account of structure—this latter being sufficient to illustrate the principles involved, care being taken not to over-elaborate structural details. Man's place in nature should be considered either in the course of zoology or in

that of anatomy. Other opportunities occur during the course in anatomy, and still more in physiology, for reference to the conditions in lower animals, and if more use could be made of these opportunities the linkage between zoology and the second-year subjects would become much more perfect, and would help in doing away with the watertight compartments into which the average student considers his early medical education to be divided.

The course in zoology should be planned so as to give the student a wide outlook on structure and function, adaptation and environment, some knowledge of the germ-cells and their maturation, of fertilization, growth, regulation, regeneration, decline and death, and an introduction to evolution, heredity and genetics—in general, it should aim at affording a broad conception of the activities and modifications of the organism as a living thing, and should educate the student to manipulate, to observe and record, and to exercise his judgment in matters of inference and of theory.

While some reference may be made in the first-year course to insects and parasitic organisms to indicate the relationship between zoology and pathology and public health, it has seemed to me for some years that the real instruction in entomology and parasitology should be given in the later part of the third or early in the fourth year along with the course in bacteriology. The first-year student, although keenly interested in the direct applications of zoology to medicine, is not competent at that early stage of his career to obtain full advantage from studies on parasites. In most universities a certain amount of time is already set aside in the third year for the study of protozoa, and of helminthes and their eggs, and I have suggested to some of my colleagues in Edinburgh that the teaching on these subjects in the first and in the third year should be brought together in the latter year and remodelled to form a short course of lectures, demonstrations and practical work to cover the essentials required for general practise in this country. By this time the student is much better fitted to appreciate the bearings of this work. I am also inclined to the opinion that a short course of six or eight lectures—on which attendance might be voluntary—on heredity and genetics would be of value in the fourth year to the good student who has a little time at his disposal.

I should be glad if my colleagues would give the section the benefit of their views on the first-year course of zoology for medical students, and on the provision of a course on entomology and parasitology about the third year of medical study.

POPULATION AND UNEMPLOYMENT[1]

By SIR WILLIAM H. BEVERIDGE

In 1876 the birth-rate in this country reached the maximum. At the same time, or just before, important steps were taken for the improvement of public health; the death-rate, which had changed little for thirty years, began to fall, and fell steadily thereafter. There followed a quarter of a century later, as a wave follows a distant earthquake, an abnormal growth in the supply of adult labor. As has been pointed out by Mr. Yule, the number of males aged twenty to fifty-five rose 19 per cent. from 1891 to 1901, as compared with a rise of 14 per cent. from 1881 to 1891, and 10 per cent. in earlier decades. If we take five-year averages the rate of natural increase (difference of birth-and death-rates) reached its highest points in the years 1876–1880 and 1881–1885. Normally, this would have shown itself first by large numbers of boys entering the labor market in the early nineties. At the same time, however, the Education Acts were withdrawing more and more boys under fourteen into the schools. The State dammed up the rising flow of juvenile labor for a year or two. The main pressure in the labor market began to be felt later, *i.e.*, about 1900, and presented itself as the "problem of boy labor," which was really the problem of those who had got boys' work easily enough between fourteen and twenty (replacing the younger children kept at school), but found themselves in difficulties when they reached man's estate. This abnormal movement was bound, for the time at least, to disturb the balance between the growth of capital needed to employ labor and the growth of labor seeking employment. Some temporary pressure in the labor market was inevitable. It might cause a check in economic progress as measured per head of the total population; it would certainly, in the bargaining between labor and capital for the division of their joint product, make labor for the moment relatively weak and capital for the moment relatively strong because scarce. Wages would lose relatively to profits.

All these special influences favor capital against labor. It is in accord with them that, of all our economic indices, that which shows worst, the only one that shows no progress at all from 1900 to 1910, is real wages, the reward to labor; that which almost alone shows continued progress at the full Victorian rate is exports, to be explained perhaps in large measure as the surplus profits of capital.

[1] From the address of the president of the Section of Economic Science and Statistics of the British Association for the Advancement of Science. Liverpool, 1923.

With these points in mind, we reach an economic interpretation of the Edwardian age, reasonable in itself and consistent with other than economic records. That age does not live in our memories and will not live in drama and fiction as a season of hard living and hard labor. It comes back to us now rather in the guise of the ball before Waterloo, as an episode of unexampled spending and luxury; as the time when we saw our roads beset by motors, our countryside by golfers, our football grounds by hundred thousand crowds and a new industry of book-makers, our ballrooms and dining-rooms by every form of extravagance. The smooth development of Victorian days was broken, but the characteristic of the time was rather inequality of fortune than general misfortune; discontent rather than poverty; a gain by capital in relation to labor, by profits in relation to wages, by some classes of workmen at the expense of others, even more than a check to our progress as a nation. Some check to our national progress there probably was, but we are not bound to believe that the check was permanent. The three factors described above—the earthquake wave of labor supply, the South African War, and the upward turn of prices—are all peculiar to their time. The relative shortage of capital would tend to produce its own corrective. Difficulty in absorbing an abnormal flood of new labor does not prove permanent overpopulation; if all the hundred million persons who now find room and growing opportunities in the United States had landed there at once they would all have starved.

In the last three years before the war we find in nearly all indices resumption of a rapid upward movement. What would have happened if the war had not come? Would the Edwardian age have proved a passing episode of unrest or the beginning of a serious threat to our prosperity? This is one of many questions whose answer is buried in the common grave of war.

In the third place, even if the new century was to see in Britain a lasting and not a transient harshening of conditions, if the rich ease of the Victorian age had gone forever with Victoria, there is little ground for surprise. Malthus or no Malthus, it was not reasonable to expect Britain to keep up forever the speed that marked her start in the industrial race. Providence had not concentrated in these islands the coal and iron supplies of all the world. As the United States and Germany and France developed their own mineral resources, Britain was destined to find her general industrial supremacy challenged, now in one field now in another; she would be driven to discover and maintain those branches of work in which she had the greatest economic advantage, and to withdraw from the rest. This process of challenge and adjustment was bound to occur

irrespective of the growth of population, and as it occurred to give rise to strains and pressures; when accomplished it might yet leave room for progress, if not at the full Victorian pace.

Of Britain before the war we may conclude that the position called for serious thought, not tears or panic. The economic records are open to diverse readings. The check to material progress in the Edwardian age may in part have been less than appears, and in part real but due to transient causes. At worst our industrial rank was challenged, not destroyed; forgetting some of the slacknesses of our easy days, we might through science and system and industrial peace have won a new lease of rapid progress. In this direction lay our remedy; in this, I think, rather than in hastening the process of birth restriction which had begun a generation before.

Let us pass to Britain after the war. Here, statistical tests of progress must be abandoned altogether. War's disturbance of our economic life and all its standards and records is barely subsiding; to found judgments of the future on the course of production or wages or prices in the years of demobilization is vanity. Judgment by recorded results is impossible; we are driven back to general considerations for an estimate of prospects in this new but not better world.

The first principle of population to-day is that under conditions of economic specialization and international trade the population problem in any particular country can not profitably be considered without reference to other countries. The problem in every country is a problem of the distribution of the population of the world as a whole. The actual density in different regions of the earth varies fantastically, according to the part which that region plays in the life of the world, from less than one person per square kilometer in Canada or three in the Argentine, through 186 in Britain, or 245 in Belgium, to 760 in Monaco or 3,538 in Gibraltar. The "optimum density" for any one country at each moment depends not solely or even mainly upon its own resources of natural fertility or mineral treasure, on its own achievements of technique or cooperation, but on how in each of these matters it compares with other countries, on whether other countries are prospering or depressed, on the relations of its own people—in respect of peace or war, of trade or tariffs—towards other peoples.

Britain illustrates this principle more clearly than any other great country, because of all great countries Britain has grown to be the least self-sufficient, the most highly specialized, the most dependent on trade and peace and worldwide cooperation. A pregnant analogy will make the position clear.

In Central Europe, before the war, lived, under one dynastic ruler, a congeries of communities known collectively as the Austro-

Hungarian Empire. These communities formed together a single economic unit, a free-trade area with fifty million inhabitants, in which every stage of economic activity, from the simplest agriculture to the most developed finance, was strongly represented, in which all the separate functions came to be distributed locally according to economic advantage without regard to internal boundaries. Some regions—east and south—were predominantly agricultural; in the northwest were extractive industries of coal and iron, and manufactures founded upon them; further south were other manufactures, and the main seat of commerce and finance. Here was timber; there water-power. Each industry tended to settle where it could most profitably be carried on. Within each industry local specialization often went very far; thus, in cotton, one region predominated in the first and final processes (spinning and bleaching), another had more than its share of intermediate processes (such as weaving); the locomotives for railways came to be built in one region and the wagons in another. In the center lay Vienna, a natural meeting-point entrenched by art in a system of radiating railways, concentrating on itself the most advanced stages of social life—fine manufactures, commerce, distribution, transport, finance, administration—a large and prosperous head directing and nourished by a large body. While the Austro-Hungarian Empire lasted, this headship brought with it the first place in prosperity. The wealth, pleasure and extravagance, no less than the government, education, science and art, of fifty millions made Vienna their center.

The war came and went, and with it went the Empire. The dynastic ruler disappeared; the congeries dissolved; each community became a separate body desiring and needing a separate head, aiming at self-sufficiency, seeking it by economic barriers against intercourse. In that break-up the average prosperity of all the fifty millions has sunk. Nearly every region is in some way poorer than before. But no region has suffered as much as Vienna; in none does the loss take the characteristic appearance of overpopulation. Vienna remains a head grotesquely too large for the shrunken body of German Austria, manifestly overpopulated, as little able to support its former numbers at their former standard as would be Monaco if the nations gave up gambling or Gibraltar if they gave up war. It is overpopulated, not through exhaustion of its natural resources, not because in the past its people were too prolific, but because the world outside has changed too suddenly.

De nobis fabula—the fate of German Austria is the moral for Britain. No other country of comparable size is so highly specialized as Britain. None produces so small a proportion of the food that it requires, or of the raw materials of its industries. None is

so predominantly engaged in the advanced ranges of economic activity; in industry rather than agriculture; in finishing processes rather than the extraction of raw material; in transport, commerce and finance, rather than manufacture. No other country, therefore, is so completely dependent upon the restoration of peace and trade and economic cooperation. None is destined to suffer so acutely from any general disorder. At this moment perhaps none is suffering so much.

It is needless to seek in excessive fecundity an explanation of our present troubles. There are other reasons, enough and to spare, why we should expect now to suffer from unexampled unemployment. Two exceptional causes of unemployment are now added to the normal movement of cyclical fluctuation. One is the difficulty of passing from war and war industries to peace—the difficulty of making swordsmen into ploughboys. The process of training and directing the new supplies of labor to fit the changing needs of industry has been broken by the war; there is a maladjustment of quality between labor supply and labor demand. The second cause lies in the damage done by the war and its aftermath to the economic structure of the world; the destruction of capital, the relapse of great nations towards barbarism, the breaking of easy and friendly intercourse, the continuance of war measures, the smaller volume of international trade and its shifting into new channels. The world has changed suddenly, if less completely, round us as round German Austria. Many of our trades find their former customers dead or impoverished or cut off by new barriers; the labor trained to those trades can not shift to fill the gap in production which is left by the disappearance of those customers and their work. In both these ways, in terms which I used in writing of unemployment fifteen years ago, we have leading instances of those "changes of industrial structure" which leave legacies of enduring unemployment, to be reduced only as the labor ill-fitted for new needs is slowly and individually absorbed again or is removed by death or emigration.

The fate of Austria has a bearing not on war alone. The world may change otherwise than by war. The "optimum density" of population for any country may be diminished not by anything happening in that country, but by the discovery and exploitation of resources in other countries; possibly even by tariff changes. The more any country is specialized in its economic functions, above all if it is specialized in the most developed rather than in the primary functions, the greater is its liability to such changes. Britain, becoming yearly less self-sufficient, setting each year a swiftly growing people to more and more specialized labor, increasing each year its inward and outward trade, was before the war taking more and

more the Austrian risk. It is arguable that with this lesson before us we ought no longer to take the risk so fully; should retrace our specialization and aim at self-sufficiency—in practical terms, under a system of tariffs or bounties, should grow more corn and do less trade. The practical answer to that argument is that we are already too far from self-sufficiency to make worth while any attempt to return. Any change great enough to diminish seriously our dependence on overseas trade, in other words our exposure to the Austrian risk, would involve an impracticable reduction in our total population and our average wealth. A middle course that is sometimes suggested is to aim at self-sufficiency in the British Empire, by tariff arrangements favoring imperial rather than foreign trade. The adoption of such arrangements clearly depends more on the wishes of the Dominions than on those of Britain, and their value for the purpose in view upon the readiness of the Dominions to acquiesce in a division of economic functions which would leave the most advanced and most profitable ones to the British Isles. It is more than doubtful whether this is the Dominion view of imperial economics. In the last analysis, the long road which Britain has travelled to dependence on international trade, as general and as free as possible, will, I believe, be found to be irretraceable. Like the hero of one of Mr. Wells's novels, the Britain that we know, the Britain of forty millions, has been made for a peaceful and cooperative world; she must try to create such a world if she does not find it ready to hand.

Let me try to gather together the threads of this long discussion. A further quotation from Mr. Keynes's writings will serve for a starting-point:

"The most interesting question in the world," he writes, "(of those at least of which time will bring us an answer) is whether, after a short interval of recovery, material progress will be resumed, or whether, on the other hand, the magnificent episode of the nineteenth century is over. In attempting to answer this question it is important not to exaggerate the direct effects of the late war. If the permanent underlying influences are favorable, the effects of the war will be no more lasting than were those of the wars of Napoleon. But if even before the war the underlying influences were becoming less favorable, then the effects of the war may have been decisive in settling the date of the transition from progress to retrogression."

The warning deserves attention. Yet, as I am less inclined than Mr. Keynes to be pessimistic about the tendencies before the war, I feel perhaps more pessimistic than he is in this passage about the effects of the war, and the possibly enduring damage it may have done and be destined to do to humanity. Another criticism that

may fairly be made upon this passage and the paper from which it comes is that in neither is it clear how large an area is referred to, whether Britain or Europe or the world.

Before the war, as I have tried to show, there is nothing to suggest that Europe had reached its economic climax; Malthus's Devil, unchained again or not, can not be found where Mr. Keynes professes to find him. For the world of white men as a whole there is even less ground for pessimism; the limits of agricultural expansion are indefinitely far. If we regard only that part of this world which is known as Britain, judgment is not so easy. Some change did come over our economic life, or certain parts of it, with the turn of the century; our effortless supremacy was challenged. Reasonable men may dispute, and since the decisive evidence has perished will probably dispute forever, whether the unrest and uncertainty of the Edwardian age marked a passing episode destined but for the war to give place to a fresh stage of swiftly rising prosperity, or, on the other hand, recorded the first shock of permanent forces working to make life in these islands less easy and to set a term to material progress.

After the war—for that phase, if indeed we have reached it, I doubt whether we may find much comfort in Napoleonic parallels. The Napoleonic wars were wars between governments and armies rather than peoples; they did not bite deeply into economic life; they left it possible for the best contemporary fiction to show a picture of English society in which the military figure chiefly as dancing partners. The war of 1914–1918 was waged on millions of non-combatants, as much as on armies; it is being continued in the same form to-day; the economic structure of the world, battered out of shape by four years of open war, is still twisted by human passions. The lesson of compulsory self-sufficiency has been learned too well; in all parts of the world, by new economic barriers, nations are endeavoring to safeguard, at the expense of their native and natural industries, the industries which were forced on them by the extremities of war. The world is poorer in resources by its lost years and ruined capital; of those diminished resources it makes worse use.

To sum up, for Europe and its races the underlying influences in economics were probably still favorable when the war began. But the war damage was great and we are not in sight of its end. Man for his present troubles has to accuse neither the niggardliness of nature nor his own instinct of reproduction, but other instincts as primitive and, in excess, as fatal to Utopian dreams. He has to find the remedy elsewhere than in birth control.

Let me add one word of warning before I finish. Examination of economic tendencies before the war yields no ground for alarm as to the immediate future of mankind, no justification for Mal-

thusian panic. This negative conclusion does not discredit the fundamental principle of Malthus, reinforced as it can be by the teachings of modern science. The idea that mankind, while reducing indefinitely the risks to human life, can, without disaster, continue to exercise to the full a power of reproduction adapted to the perils of savage or prehuman days, can control death by art and leave births to nature, is biologically absurd. The rapid cumulative increase following on any practical application of this idea would within measurable time make civilization impossible in this or any other planet.

In fact, this idea is no more a fundamental part of human thought than is the doctrine of *laissez-faire* in economics, which has been its contemporary, alike in dominance and in decay. Sociology and history show that man has hardly ever acted on this idea; at nearly all stages of his development he has, directly or indirectly, limited the number of his descendants. Vital statistics show that European races, after a phase of headlong increase, are returning to restriction. The revolutionary fall of fertility among these races within the past fifty years, while it has some mysterious features, is due in the main to practises as deliberate as infanticide. The questions now facing us are how far the fall will go; whether it will bring about a stationary white population after or long before the white man's world is full; how the varying incidence of restriction among different social classes or creeds will affect the stock; how far the unequal adoption of birth control by different races will leave one race at the mercy of another's growing numbers, or drive it to armaments and perpetual aggression in self-defense.

To answer these questions is beyond my scope, as it is beside my purpose to pass judgment on the practises from which they spring. The purpose of my paper is rather to give reasons for suspending judgment till we know more. The authority of economic science can not be invoked for the intensification of these practises as a measure for to-day. Increased birth control is not required by anything in the condition of Europe before the war, and is irrelevant to our present troubles. But behind these troubles the problem of numbers waits—the last inexorable riddle for mankind. To multiply the people and not increase the joy is the most dismal end that can be set for human striving. If we desire another end than that, we should not burk discussion of the means. However the matter be judged, there is full time for inquiry, before fecundity destroys us, but inquiry and frank discussion there must be. Two inquiries in particular it seems well to suggest at once.

The first is an investigation into the potential agricultural resources of the world. There has been more than one elaborate examination of coal supplies; we have estimates of the total stock

of coal down to various depths in Britain and Germany, in America, China and elsewhere; we can form some impression of how long at given rates of consumption each of those stocks will last; we know that "exhaustion" is not an issue for this generation or many generations to come. There has been no corresponding study of agricultural resources; there is not material even for a guess at what proportion of the vast regions—in Canada, Siberia, South America, Africa, Australia—now used for no productive purpose could be made productive; at what proportion of all the "productive" but ill-cultivated land could with varying degrees of trouble be fitted for corn and pasture. Without some estimate on such points, discussion of the problem of world population is mere groping in the dark. The inquiry itself is one that by an adequate combination of experts in geographic and economic science—not by a commission gathering opinions or an office gathering statistical returns—it should not be difficult to make.

The second is an investigation into the physical, psychological and social effects of this restriction of fertility which has now become a leading feature of the problem. This also is a matter neither for one person—for its scope covers several sciences—nor for a commission; facts rather than opinions or prejudices are required.

If the question be asked, not what inquiries should be made but what action should now be taken, it is difficult to go beyond the trite generalities of reconstruction, of peace and trade abroad, of efficiency and education at home. The more completely we can restore the economic system under which our people grew, the sooner shall we absorb them again in productive labor. Unless we can make the world again a vast cooperative commonwealth of trade, we shall not find it spacious enough or rich enough to demand from these islands the special services by which alone they can sustain their teeming population. Even if the world becomes again large enough to hold us, we shall not keep our place in it with the ease of Victorian days; we dare no longer allow, on either side of the wage bargain, methods which waste machinery or brains or labor. Finally, if there be any question of numbers, if there be any risk that our people may grow too many, the last folly that we can afford is to lower their quality and go back in measures of health or education. Recoil from standards once reached is the gesture of a community touched by decay.

THE IDENTITY OF INHIBITION WITH SLEEP AND HYPNOSIS[1]

By Professor IVAN PETROVITCH PAWLOW
PETROGRAD

THE subject of this address is the highest nervous activity of the dog. I have studied this activity with numerous collaborators during the last twenty years. The investigation has always been conducted on a purely physiological basis, psychological conceptions or words having never been used.

This highest nervous activity consists of analysis and synthesis of the outer and inner world. In other words, it consists of analysis and synthesis of stimulations which reach the cerebral hemispheres from without or from within. This means that it consists of connections and disconnections of different points of this part of the nervous system. Analysis and synthesis are accomplished with the aid of two processes—stimulation and inhibition.

The chief basis of all nervous activity consists of so-called reflexes or instincts, the latter being the more complex reflexes. Reflexes are the inborn connections between definite outside agencies and corresponding definite activities of the organism. This reflex activity is the function of the lower parts of the cerebral nervous system. During the life of the individual, temporary connections are formed in the cerebral hemispheres, under special conditions, between agencies and physiological activities, in accordance with the principle of signalization adopted. I term inborn reflexes "unconditioned reflexes," those individually acquired "conditioned reflexes." If the action of a previously indifferent external agent coincides a number of times with an inborn reflex, it acquires the power of producing exactly the same reaction as the unconditioned reflex. For example, food initiates a number of reactions, *i.e.*, the animal performs certain movements with regard to food and secretion of saliva and gastric juice occurs. If the feeding of the animal coincides a number of times with a certain sound, previously entirely indifferent, it evokes the same reactions as the food itself. The easiest way to gauge the intensity of this reaction is to measure the amount of the secreted saliva. A similar procedure may be applied to the formation of conditioned reflexes caused by any other agent of the outer world, as in the case of self-protection and sexual instincts. But in this discussion I will refer only to the food instinct.

[1] Abstract of a lecture delivered at the University of Chicago, July 5, 1923.

Conditioned stimuli act as signals for unconditioned reflexes; for this reason they always require correction. If the conditioned stimulus is not accompanied by the unconditioned one, the former temporarily loses its stimulating action. For instance, if, in the example already mentioned, the sound is not accompanied by feeding, it eventually loses its food reaction. But after an interval of several minutes, or in some cases, hours, this reaction spontaneously returns. In this case we are dealing with an inhibition of the reflex and not with its destruction. To take another example. If, to an established conditioned reflex, any indifferent agent is added, and this combination is not accompanied by feeding, then the conditioned stimulus used in the combination gradually loses its stimulating action. This is also a case of inhibition. The inhibition, which in this way always affects the synthetical activity, plays an important part in the analytical activity also. In the formation of a conditioned reflex the following law holds: Every agent, after becoming a conditioned stimulus, has a very generalized type, *i.e.*, the conditioned reaction is provoked not only by the specially chosen stimulus, but by any one of the same type. Making use of the inhibitory process, all these similar agents may be deprived of any stimulating action, and a very perfect differentiation of the primary action may be thereby obtained. In order to get this result it is necessary to apply repeatedly, in the absence of feeding, the agencies which had become spontaneously active, and during the same interval of time to reinforce the original conditioned stimulus, *i.e.*, to accompany it by feeding; in other words, by an unconditioned reflex. In this way the highest degree of analysis of which a given animal is capable is realized.

After this introduction I can now proceed to the main subject of my address. As the result of many preliminary guesses and tests we have arrived at the following thesis: Inhibition, ordinary sleep and hypnosis are one and the same process. This is a fundamental fact which has long attracted our attention in the course of the study of conditioned reflexes. Every conditioned stimulus, as soon as it is used alone without being accompanied by an unconditioned one, leads, early or late, to a drowsy state or to sleep. The difference between the various experiments is quantitative only. Some definite agents, used as conditioned stimuli, produce sleep in a shorter time than others. In a similar way some animals develop this response more easily than others. As a general rule, sleep is induced the quicker, the longer the conditioned stimulus acts alone without being accompanied by an unconditioned one. Experiments frequently show the following striking features: We have, for example, in our laboratory a dog which, when not fed for about

twenty hours, is always greedy for food. The conditioned stimulus, after being used during fifteen seconds by itself before the actual feeding, at first invariably produces the feeding reaction, motor and secretory. During these experiments the dog always remains wide awake. Now, if we make the interval of time of the action of the conditioned stimulus, in the absence of feeding, longer (say thirty seconds), after a few (three to five) repetitions the dog gets drowsy, and at the end falls so soundly asleep that to take food at the end of thirty seconds he has to be forcibly awakened.

This circumstance may be most easily understood as follows: The isolated, concentrated stimulation of cells of the hemispheres presently leads to their exhaustion and to sleep, if not interchanged and not accompanied by the stimulation of other cells. We know that normal sleep supervenes as a result of general exhaustion of the hemispheres. In this particular instance the only point which is not quite clear concerns the manner of spread of the inactive state from the exhausted cells to those cells which had not been involved in work. It may be assumed that the exhaustion of certain cells causes the formation of some unknown substance or process, which in its turn produces an inactive state of the exhausted cells and spreads to other (fresh) cells.

In support of the sleep-inducing action of the conditioned stimuli under special conditions may be adduced a similar well-known fact, that uniform and monotonous surroundings usually predispose to sleep in persons who are not even tired.

This condition, which in the case of conditional reflexes leads to sleep, is exactly the same as that which leads to the development of inhibition. Every time that the conditioned stimulus is not accompanied by an unconditioned one, it is gradually inhibited. Further, whenever the inhibition is developed in a definite phase, sleep follows, if special precautions are not taken to prevent it. Finally, cases are constantly met with in which either inhibition or sleep may develop, or inhibition may pass into sleep, or vice versa, or both conditions are present and are added to one another. These considerations have led us to the conclusion that inhibition and sleep are identical processes.

But how is it that inhibition is a constant and essential element of the active state of the hemispheres, and sleep of a resting state? The answer does not seem to be difficult. Inhibition is partial sleep, or sleep distributed in localized parts, forced into narrow limits; true sleep is a diffused and continuous inhibition of the whole of the hemispheres. The distribution and division of inhibition, the forcing it into narrow limits, is accomplished by means of an opposing process of stimulation. The formation of points of stimulation

in the hemispheres is a reliable and constantly used method for limiting inhibition or for dispelling sleep.

The following examples may be cited: A dog is falling fast asleep when the conditioned stimulus is applied thirty seconds in advance of the feeding. In order to avoid sleep, it is now necessary to form new conditioned stimuli, using new agents to stimulate new points of the hemispheres, whilst at the same time making the intervals between the new stimuli and feeding shorter. The first stimulus, separated from its associated feeding by thirty seconds, and applied in the intervals between the newly produced stimuli, no longer causes sleep.

We can, however, differentiate the related stimuli from our original conditioned stimulus by repetition without feeding. If we do this the stimuli gradually lose their stimulating action; at the same time the animal grows drowsy and finally falls asleep. It is only when the differentiated agents are alternated with the original conditioned stimulus that the sleeping state is gradually dissipated and the pure inhibition of these differentiated agents alone remains.

A variation of this experiment may also be mentioned. With mechanical stimulation of different points of the skin, it may be often observed that the inhibition which is produced from one point is unable to affect a point which has been much more highly exercised; nor can it pass this point.

These facts imply the idea that the processes of inhibition and sleep are capable of spreading over the area of the hemispheres. This assumption can be verified by direct experiment.

The chief merit of the physiology of conditioned reflexes consists in the fact that it has undoubtedly proved that inhibitory processes have the property of spreading (irradiation).

Let us place on the skin of the animal a series of instruments, producing mechanical stimulation of the skin. Let us form the conditioned stimuli out of all these mechanical stimuli in such a way as to obtain the same quantity of saliva from each of them. Now let us differentiate a point at one end of the series. Using the procedure described we can make the corresponding stimulation inactive. This means that we produce inhibition in the corresponding point of the brain. Then by observing the effects which are produced at the active points at different intervals following stimulation at the selected initial point, we easily recognize that the inhibition from the initial point first irradiates at a definite rate over the active points and afterwards again concentrates itself at the initial point. It is a fact of great interest that this movement of the inhibitory process is very slow—it is measured in minutes. In our daily experience we encounter exactly the same fact concerning

sleep, which gradually takes possession of the hemispheres and then, after a certain period of time, leaves them. Of no less interest is the fact that the rate of irradiation of the inhibitory process varies widely in different animals. It may be ten times greater in one than in another. This is in complete accordance with the circumstance that different persons fall asleep and awake at different rates. I regard the facts mentioned as proving conclusively the identity of inhibition and sleep.

From this point of view the phenomenon of hypnosis may be easily understood. It represents one of the different steps in the process of irradiation of inhibition over the mass of the hemispheres —the partial sleep of the hemispheres. We have often observed the following striking phenomenon in the dog. We produce inhibition by any known method and give time for it to irradiate until the following definite stage is reached: A chosen conditioned stimulus still affects the secretory reaction; the saliva flows, but the animal does not take food which is offered to it. This means that inhibition has taken possession of the motor area of the hemispheres, but has not yet irradiated to other parts of them; those, for instance, which are in connection with the eyes, the ears, and so on. This is obviously analogous to a special phase of human hypnosis, when the hypnotized person hears you and understands you, but can not make any voluntary motion.

Thus the hemispheres, in an active state, show an enormous mosaic of points stimulated and inhibited (or sleeping) which are very close and mixed up with one another.

Hypnosis is inhibition spread over the usually active points in special areas of the hemispheres.

Sleep is inhibition irradiated over the whole area of active points of the hemispheres and even over some parts of the brain below the cerebral hemispheres.

But even when the inhibition is widespread there still remain certain isolated active points (so to speak, on the alert) which are capable of being stimulated. We know this from daily life; a miller is awakened by the stopping of his mill, a mother is roused by a movement of her sick child. Similar facts may be observed in dogs and may be artificially produced.

The process of inhibition is one the development of which is to a great extent dependent upon practice. This may supply the foundation for a hygiene of inhibition in both active and sleeping states.

A question of great importance is, whether the highest nervous activity—individual perfection—may be of use to the next generation, *i.e.*, whether it may be inherited. We have tried to find an

answer to this question, and have obtained certain experimental results. We established the conditioned food reflex in white mice, making use of the sound of an electric bell. With the first set of (wild) white mice it was necessary to repeat the combination of ringing the bell and feeding three hundred times in order to produce a well-established reflex. The second generation formed the same reflex after a hundred repetitions. The third generation acquired this reflex after thirty repetitions, the fourth after ten and the fifth after five only. The experiments had reached this point when I left Petrograd this summer. On the basis of these results I anticipate that one of the next generations of our mice will show the food reaction on hearing the sound of the electric bell for the first time. This result would be analogous to the well-known fact that a newly hatched chicken immediately tries to peck small objects or spots which it sees on the floor. If the stimulation of an eye, as in this case, leads to the food reaction, why may not the stimulation of the ear in the former case produce the same effect?

PLANTING IN THE NATIONAL FORESTS

By C. G. BATES

FREMONT FOREST EXPERIMENT STATION, U. S. FOREST SERVICE

THE writer having been identified, if only in a modest way, with the early struggle for the forest conquest of the Nebraska sandhills, and, because of interest in this struggle, having followed the technical problems which have been encountered in other similar undertakings, may pretend to speak of the planting work on the National Forests with some authority, even though not strictly engaged in this line, but rather with forest investigations in general.

If we may, only seventeen years after the beginning of such work by the Forest Service, look at the progress of planting in retrospect, there is one fact which stands out preeminently, and that is that the marked successes have almost without exception been in localities in which the soils are relatively light. This is most strikingly illustrated by the barren sands of Nebraska, but is hardly less true in Michigan, Minnesota, the Pike's Peak region of Colorado and even with the planting of maritime pine in Florida. The reason for these successes is not far to seek, for all the large-scale planting has been done with coniferous trees and a large proportion of it with representatives of the genus *Pinus*. Not only has it long been recognized that the pines *will grow* on light, infertile soils usually unsuitable for agriculture, but recently at the Fremont Experiment Station we have obtained direct evidence that as a general rule soils of meager fertility are much more likely to stimulate vigorous growth of the pines. A complete explanation of this is not yet available, but it appears that a poorly leached soil which accumulates fertility (nutrient salts) useful to such highly developed trees as spruces also accumulates some salts which are definitely toxic to the pines. In nature the necessary leaching to prevent any dangerous accumulations of salts is usually secured through one of the following conditions:

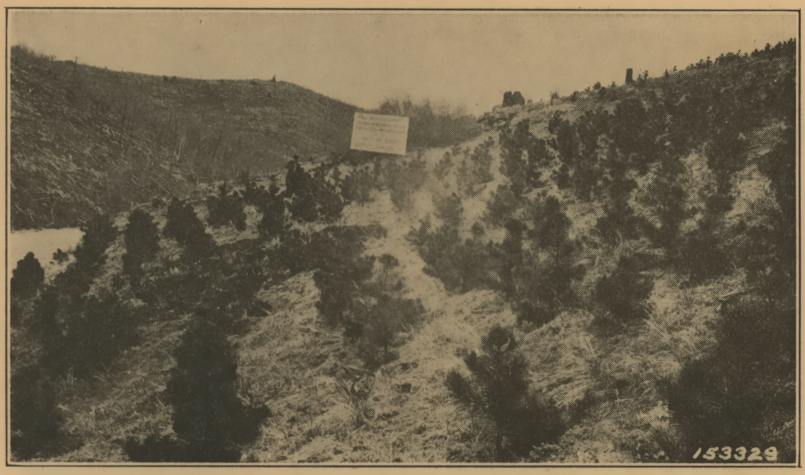
(1) Extreme porosity of the soil.
(2) Steep slopes and free sub-drainage, as on mountains.
(3) Heavy precipitation with some drainage.

Another fact which has been strikingly brought out by the National Forest planting is that many areas in which either natural seeding or artificial seed distribution by man have failed to generate forest growth may be readily reclaimed by the planting of

RUGGED MOUNTAINS OF THE PIKE'S PEAK REGION, DEVASTATED 60 YEARS AGO

the proper kind of nursery stock. So far, the cases of this kind which have been encountered may be characterized by the fact that the soils are rather loose, drying quickly at the surface, and the atmospheric conditions are also highly conducive to quick drying, with the result that, even if rains occur rather frequently, there is little chance for seeds to germinate and rarely time enough for the roots to penetrate to a safe depth. The key to the situation lies in these words "safe depth," for usually a soil which dries quickly at the surface retains well its moisture a little deeper. The success of planting on such sites, where seeding has failed, is due entirely to the fact that the roots of planted trees are at once placed at a depth where drought seldom reaches.

Another great obstacle to natural reseeding is the competition of established vegetation, such as a grass sod, and this obstacle is not so easily overcome by planting, for very often the roots of these smaller plants, already established, penetrate as deeply as can the roots of the newly planted tree. The mere mechanical act of excavating for the tree, however, destroys existing roots in a small space, and gives the tree a temporary advantage. At this stage, then, success or failure depends very much on vigor and proportion of the nursery stock. Without going into details of nursery technique, it may be said that the Forest Service has learned well the lesson of using only trees with well-developed roots and fairly small tops. It is interesting to observe that western yellow pine, the most "drought-resistant" tree of the Central Rockies, suffers particularly in planting if the nursery stock is too old or too large. There is, naturally, a limit to the amount of root that can be planted



BEAUTIFIED AND RECLAIMED BY THE PLANTING OF WESTERN YELLOW PINE, NOW 10 YEARS OLD

with economy, a maximum length of about 12 inches ordinarily. Yellow pine trees usually have only a few such roots. If, then, the top is disproportionately large, the loss of water by transpiration from it may easily exceed the intake of water by the roots. The interesting fact is that which has been demonstrated experimentally, namely, that relative to other species the yellow pine is not at all conservative of water. For trees of uniform size yellow pine will transpire more water than their associates, such as Douglas fir and spruce. Any appearance the pine may have, therefore, of being "drought-resistant" is due entirely to the fact that, as it develops naturally, it sends its roots down quickly and vigorously to the safe moisture zone of the soil.

The competition of other vegetation can only be avoided by sowing or planting before this other vegetation establishes itself, as, for example, immediately after a destructive fire. This is the natural method by which millions of acres of lodgepole pine have become established in the Rocky Mountain region, this species having no claim whatever to drought-resistance, but merely a fortunate manner of carrying its seeds through fire. This principle being well established, practically no seeding is being done on the National Forests to-day except on new burns, and for the sake of economy planting is also being restricted to areas in which competition is not keen.

The Roubaix Area in the Black Hills is one of historical interest which beautifully illustrates the principle outlined above. Broadcast seeding on this area was started in 1904 or 1905, very

THESE PLANTATIONS BORDER THE PIKE'S PEAK AUTO HIGHWAY AND FURNISH INSPIRATION TO THOUSANDS OF AMERICANS

soon after an extensive and completely destructive fire. At first the success of the yellow pine seedlings was phenomenal. Each year's seed-sowing, however, was less productive, and by 1910 the failures were almost absolute. Following this, even planting of nursery stock was attended with much difficulty.

As a result of the early success of seed sowing, much similar work was done elsewhere under less favorable circumstances, a large proportion of it being wholly unsuccessful. Foresters were very much at a loss to explain these facts, since the history of the Roubaix area could not be closely correlated with any change in weather or climatic conditions, until finally it was realized that in a few years this area had gone through a complete vegetative transition, a heavy sod having been formed.

The Nebraska sandhill planting and most of its technical problems having been fully discussed in a government publication, it it not my intention to mention it further in this connection, but rather in a more sentimental way as the most striking success in technical forestry which may be credited to the Forest Service. The writer having known these sandhills, in childhood, in their most desolate and unattractive condition when being heavily overgrazed, can perhaps appreciate better than the average person the miracle that has been wrought by the perseverance of a handful of pioneering foresters. It will do no harm to pay tribute here to Scott, Mast, Bessey, Pierce, Johnson and Higgins as the outstanding figures whose personal labors have accomplished this remarkable thing. It is indeed unfortunate that the locality of this work is

HERE ARE NEBRASKA SANDHILLS IN AN UGLY MOOD, GRAZED TOO HEAVILY

not much visited by Americans in general. It is, however, still possible for any one traveling to the Northwest, via the C. B. & Q. railway, to obtain a distinct impression of the accomplishment, if not a knowledge of its details, for soon after leaving Broken Bow, Nebraska, the train enters the sandhill region, and on both sides of Halsey there is opportunity to observe the stark nakedness of the country. If one has come from the West, after riding through the flat plateau region around Alliance, and then three or four hours of sandhill landscape, he will be fairly smitten by the contrast with the several miles of pine-clad hills which near Halsey lie to the south of the railroad and the Loup River. One must see the pines against snow to obtain a clear detailed picture of their development, and to realize that their presence has indeed recreated the region, but even at midsummer their dark green is a decided contrast to the pale vegetation and the glistening sand of the hills. On entering one of the older plantations one finds himself surrounded by trees now at least twenty feet high, sending their tips skyward at an altogether surprising rate. Surely there was divine inspiration given to the man who first conceived the possibility of this, the late beloved botanist, Charles E. Bessey.

Planting on the National Forests having now become more or less stabilized, being limited in scope by the funds available, the time has arrived when a study may be made of such questions of technique as affect both the cost, the immediate success and the ultimate productivity of the work. Of these considerations, the last deserves most consideration, because the factors involved are

AND HERE A FEAST FOR HUMAN EYES—JACK PINE PLANTED IN 1911

comparatively obscure. Some of the factors involved in the ultimate value of plantations, which may at this stage appear very promising, are method of planting, species used and variety or geographic form of the species.

Those familiar with forestry literature will recall that for years a controversy has raged in Europe as to whether planted trees develop normally, that is, as soundly and as well as trees coming directly from the seed. It may be said that as yet in the United States we have only an echo of this controversy, no observed cases of maldevelopment having been reported from our plantations. Our analysis of the matter is merely this, that when trees with a considerable mass of roots are planted, there is a chance that all the existing roots may be placed in the soil in a ropelike mass, instead of being spread as a network through the soil. There is, then, some danger that there will be no spreading of the roots immediately below the surface, bracing the tree to the fullest extent, and that as a result the tree may show a lack of wind-firmness. There is also danger that the roots so placed in contact may, as they develop, graft together, adding a chance for the development of decay. These considerations are with us still entirely theoretical, but they must be borne in mind. Particularly in the sandhill planting, where the trees are set in slits, observation on existing trees may develop the need for a different planting practice.

With the exception of western yellow pine, all the species planted in the Nebraska sandhills have been exotics to the region, and even this species can hardly be called "native." Jack pine

A Successful Plantation of Scotch Pine, Dating Back to 1910. Probably the Riga Variety

from the Lake States region has found great favor, because, like most weeds, it grows very vigorously in youth, but of course, it has very limited possibilities for development in size. Now that the plantations are attaining some age, it is interesting to note that two European species, which have not particularly recommended themselves because of relative difficulty in the initial stages, are making excellent showing. These are Austrian pine and Scotch pine, the successful plantation of the latter being undoubtedly of the Riga or northern variety.

Little or no success with exotics in other national forest plantings can be mentioned, so that plans have gradually settled down to consideration only of the native, well-tried species. This is partly because in the Rocky Mountain region, generally speaking, the temperatures are low and the growing season short, and partly because the prevailingly dry atmosphere calls for certain adaptations, for the conservation of water, which the exotics as a rule have not developed. Thus, a majority of exotics tested have survived the first summer after planting, and even a succeeding winter if fully covered by snow, but the foliage is quickly burned when exposed to the dry winter winds. Again, Austrian pine in the foothills and Scotch pine at middle elevations promise to be partially successful, but not in a degree to warrant the hope that the native types of timber may be improved upon.

Finally we come to the question of varieties. It has taken many years of experience and considerable educational activity on the part of ecologists to bring foresters to a realization that climatic

conditions have a most decided effect on the character of the native vegetation, that climatic conditions may vary widely over the range of a given species, and in very essential respects, and that in consequence, by adaptations to these different conditions, a given species may develop climatic varieties which from a practical standpoint are just as different as though they comprised distinct species. Western yellow pine furnishes as good an example of this as any, having a very wide range. Forms of western yellow pine from California and Oregon have been incapable of surviving the winter conditions in the Central Rocky Mountains, even in a well-sheltered nursery. On bringing together the Montana, Colorado and Arizona forms of this species, in Colorado, differences are plainly visible: Both the northern and southern forms are much less adapted to withstand severe exposures than the indigenous form, and laboratory tests show that the three varieties give quite different reactions to light and moisture. It is, then, perfectly apparent that we have in the national forests the same problems of seed supply which have for years vexed European foresters, and probably even more acute problems because of more varied climatic conditions. This and the coordinate matter of individual selection and breeding are problems which deserve the most careful consideration by research workers, and meanwhile should give rise to extreme caution on the part of practitioners.

Forest planting on the national forests has undoubtedly had its most trying experiences and is mainly beyond the experimental stage. Entirely satisfactory progress is being made on the larger projects in which activity is centered. The present need is for expansion in the rate of planting in order that several million acres of barren land may quickly be placed on a productive basis.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

THE SHUT-EYE SKEPTIC

THE history of science follows the plan of the catechism. Each new topic begins with a question. "First catch your hare. Then take it apart," was the rule of the old cook book. "First catch your fact. Then take it apart," is the rule of scientific procedure.

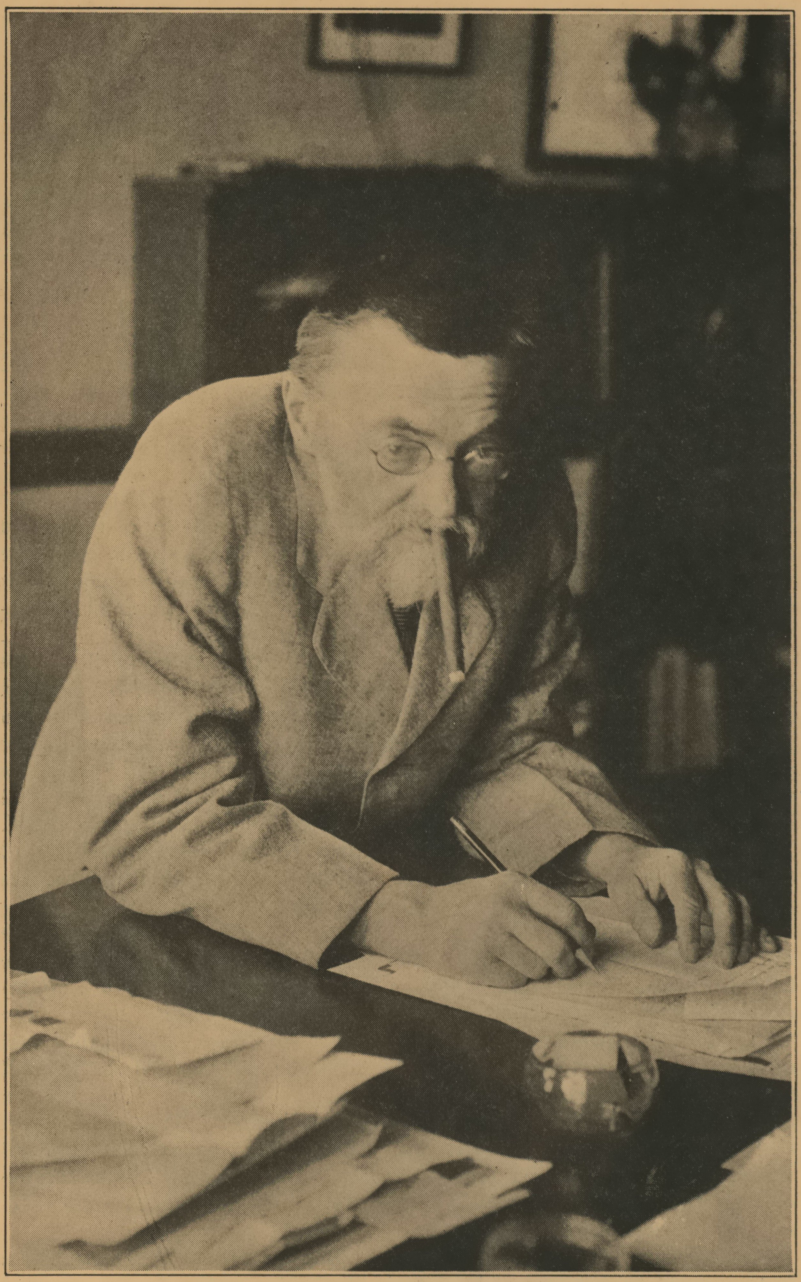
Whenever a scientist is called upon to explain something strange he asks "Is it so?" before attempting to account for it. He knows the natural credulity of man so well that he is very reluctant to accept on anybody's say-so an unverified statement.

This is what is known as "scientific skepticism," which is quite the proper attitude of mind if taken in its primary meaning. For the skeptic is, by derivation of the term, the man who sees, who looks into things, who keeps his eyes open. But on account of the natural tendency of words and men to deteriorate the skeptic may in the course of time come to mean one who shuts his eyes and refuses to see what is plain to other folks. For that reason science has had sometimes to retrace its steps and pick up something that it had overlooked or deliberately rejected.

An amusing instance of this is found in the history of meteorites. The ancients saw nothing incredible in the falling of stones from heaven. Heaven was to them only a sort of upper story of the earth. It was a roof to the world, just high enough to clear the mountain tops and quite as substantial. That there were chinks in the blue-painted ceiling could be seen at night when light leaked through, and it was not surprising that occasionally a stone got knocked off the battlements like a tile from a roof. The gods, especially Jupiter and Thor, threw stones and thunder-bolts at one another in their upstairs quarrels, and sometimes missed their aim, like mortals, and then these missiles fell to the earth.

So we find learned men, like Livy, Pliny and Plutarch, recording the fall of meteorites, together with other information, true and false, in the field of "meteorology." But when we come down to the "Era of Enlightenment" of the eighteenth century we find arising a skeptical spirit. The old myths and superstitions were ruthlessly swept away and with this mass of rubbish a few grains of truth. The telescope had knocked the roof off the world and removed the stars to unmeasurable distance. It was known that above the earth and below it was empty space. There was no loft aloft in which stones could be stored. The museums which had preserved stones said to have fallen from heaven took them out of the exhibition cases and threw them away lest the museum should be laughed at for preserving such relics of superstition.

Nevertheless stones continued to fall. But rarely and in remote places so they could be disposed of by denial. In 1751 a meteorite was reported to have fallen in Agram. But Agram was inhabitated by southern Slavs who could not be expected to know any better. In an enlightened land like Germany they knew better, at least they had learned better by 1790, when Professor Stuetz wrote "that iron should fall from heaven might in 1751 have been believed even in Germany by sensible people on account



CHARLES PROTEUS STEINMETZ

At his desk in the laboratories of the General Electric Company. His death at the age of fifty-eight years is a serious loss to electrical engineering

of the then prevailing ignorance of natural history and physics, but in our time it would be impossible for such fables to find credence."

But in that same year, 1790, a meteorite fell in Juillac, France. It came blazing through the sky and exploded with such a bang that everybody there knew about it and fragments could be picked up. The mayor of the town sent in to the French Academy of Sciences a report of it attested by three hundred witnesses.

What do you suppose that learned body did with the document? You might know if you had had any experience with such bodies. The matter was referred to a committee.

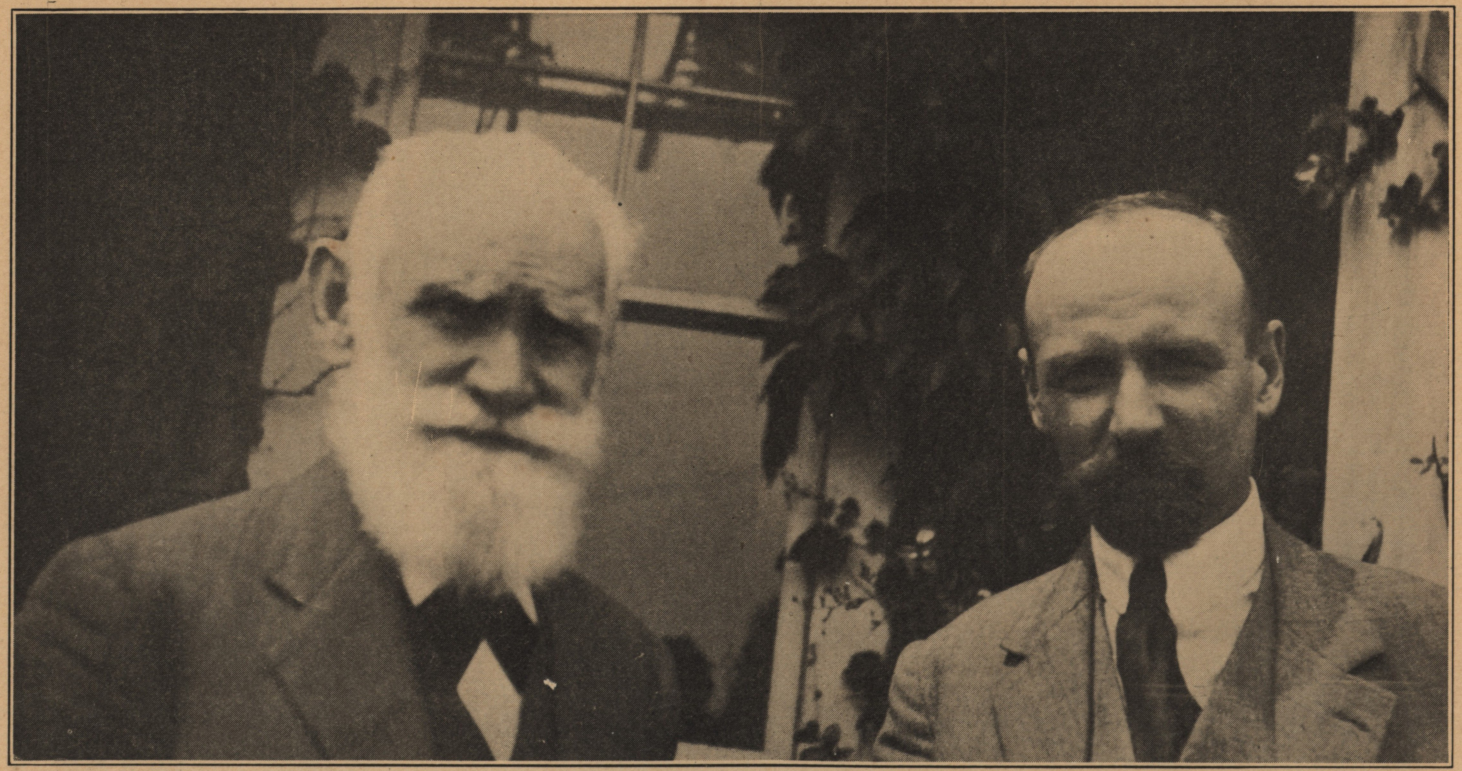
But the referee, M. Bertholon, could see in it nothing but a deplorable example of the persistence of popular credulity. In his report to the academy he expressed his pity for the community which had a mayor so stupid as to believe such stories. "Is it not sad," he said, "to see a whole municipality attesting in a formal protocol to a popular superstition? The philosophical reader can find nothing to say when he sees this authenticated testimony to an obviously false statement, a physically impossible phenomenon." The savant, A. Deluc, expressed the prevailing attitude more emphatically when he declared that if such a stone should fall at his feet he would have to admit that he had seen it but he could never believe it.

But what was then so impossible that a wise man would refuse to believe his own eyes is now universally accepted. The museums again take pride in exhibiting meteorites. The biggest known, a mass of meteoric iron weighing more than thirty-seven tons, brought by Peary from Greenland, may be seen at the entrance of the American Museum of Natural History at New York. And it is estimated that 100,000 tons of meteoric dust and stones fall annually upon the earth. Every fall and find is eagerly examined to see if it brings us any news of other worlds than ours. But of the thirty elements found in meteorites there is none that was not already known on earth, though the combinations and proportions are somewhat different. These visitors evidently come from where water and air are limited or lacking, but otherwise they are made of much the same stuff as our own earth.

BACTERIA RUN ENGINES

In India, where the elephant was first tamed for power, bacteria are now being cultivated for the same purpose. This descent in the course of centuries from the largest to the littlest of living creatures is likely to prove a gain in efficiency, for the microbe will feed on sawdust and does not even need air to breathe.

The rodlet bacteria that are being colonized for the running of dynamos thrive best in dark air-tight tanks of sewer sludge and sawdust kept at a temperature of 95 degrees Fahrenheit. Under these conditions they multiply amazingly and set about converting the septic slush into harmless and indeed useful compounds. One of the products of their activity is acetic acid which might be used for vinegar—if you did not know where it came from. The fermentation of the cellulose of the woody stuff gives also gases, chiefly carbon dioxide and methane. The former could be used for charging soda-water if it were worth while. The methane is, however, of real value since it is the best of gases for motor fuel or for heating or with a Welsbach mantle for lighting. Natural gas from wells is about nine tenths methane.



PROFESSOR IVAN PETROVITCH PAWLOW

With his son who accompanied him on his recent visit to the United States. The photograph was taken by Julian P. Scott

The method of making methane by fermentation with the aid of the airless bacteria is not new. In fact, it was first found bubbling up from the decaying vegetable matter in stagnant pools and was formerly called "marsh-gas." If you look in one of the old text-books of chemistry, in the days when they had space for such interesting little items, you will find a picture of a boy collecting the bubbles of the escaping gas with an inverted funnel and lighting it. But our grandfathers, being impractical and imprudent creatures, although fortunately for us curious in nature's ways, thought of marsh gas only as a plaything and never dreamed of setting it to work as we do now-a-days.

In the Ruhr region of Germany a large municipal sewage plant has been constructed so as to save the gases given off from the fermentation of the sludge by putting concrete hoods over the digestion tanks. This gas contains from 65 to 90 per cent. of methane and sometimes hydrogen up to ten per cent. The gas is better than the ordinary city gas. In fact, it has about twice the heating value per cubic foot of that furnished by the gas plant of Essen. From the Ruhr experience it is estimated that by employing the proper bacteria a city of 100,000 inhabitants could get eleven million cubic feet of combustible gas a year out of its sewage sludge.

A Dutch manufacturer of strawboard was much annoyed when the government ordered that the waste liquor from the wood pulp should not be allowed to flow into the river, but should be run into storage tanks for settling and filtration. It seemed a bother and expense to the manufacturer, but he found that if the tank were inoculated with the proper bacteria and kept warm and closed a gas could be collected from it of twice the volume of the liquid. This gas contained from 70 to 77 per cent. of methane, the rest being carbon dioxide. The methane was run into gas-holders and used in internal-combustion engines for running dynamos that furnished light and power for the works, and the surplus gas was sold to the local gas works which mixed it with 25 per cent. of coal gas and used it for the town. It has been found possible in India to get by fermenting banana stems and skins a gas containing 81 per cent. of methane and 14 per cent. hydrogen.

It has often happened that the government, in suppressing a public nuisance, has forced a factory to make a profit out of a waste product. It has come to be a proverb in engineering circles that "Wherever there's a nuisance there's a waste and wherever there's a waste there's wealth."

A PLEA FOR A SCIENTIFIC THEOLOGY

The editor of "Christian Education" asked me to point out the defects of theological seminaries. Of course I complied. It is fun to find fault with anything when you are not to be held responsible for making it better.

I never took a course in a theological seminary, but one can judge something of the workings of a factory from its output. And I remembered what Dr. Oliver Wendell Holmes replied when the preachers asserted that he had no right to meddle with questions of theology since he had had no training in that field. He said—if I do remember it—that after he had listened to medical lectures for three years he was made doctor of medicine with the right to practice and teach, but that after he had listened to theological lectures for thirty years he was not considered competent to express an opinion on the subject.

Theology is a free-for-all field from which not even professionals are barred. And if the professionals do not take advantage of the new opportunities that science is opening to them, it is likely to pass mostly into the hands of amateurs.

So possibly the readers of THE SCIENTIFIC MONTHLY, who mostly belong to the amateur class of theologians, may like to see my criticism of present-day theological graduates. It was:

"I do not know enough about the curricula of theological schools to suggest any improvements. Their graduates are good fellows, energetic, earnest, ambitious and liberal-minded. They seem to be smartly up-to-date in all respects but one, and that is theology. Most of them do not seem to have any or any interest in any. By theology I do not mean a particular system of dogmatic doctrine but rather the habit of thinking about the fundamentals of faith and reason, about the metaphysics that lie at the base of physics, the psychology that controls character and motivisation, the personal philosophy that is the compass of conduct. It is the schools of science, not the schools of theology, that are turning out the thinkers in such fields.

"We are in the midst of the greatest revolution of thought that the world has ever seen, the Einstein theory of relativity, the Planck theory of quanta, the chromosome theory of heredity, the hormone theory of temperament, the new knowledge of the constitution of the universe and of the workings of the human mind, these ideas will influence the philosophy, theology, religion and morals of the future as much as did the Copernican theory in the sixteenth century and the Darwinian theory in the nineteenth. Such questions would have aroused the keenest interest in the minds of men like Edwards, Berkeley, Calvin, Aquinas or Paul. A student in engineering or biology will sit up half the night discussing these theories, but your modern theological graduate is bored by them. He has learned how to give the glad hand to the strangers at the church door and can teach boy scouts how they should salute the flag—things that a pump-handle or drill-sergeant could do as well—but he is not qualified to lead his people through the mazes of modern thought. Since sermons have become sociological instead of philosophical serious minded people are going elsewhere to get their metaphysics and often getting a poor brand of it from unqualified dispensers. When a young preacher does touch upon such topics —which is fortunately seldom—he is apt to reveal a materialistic conception of matter that sounds amusingly antiquated to his scientific hearers.

"It might be said that the present situation is an improvement over the old since the clergy, as a rule, no longer fight such new theories as they did Copernicanism and Darwinism. But I am not sure of that. A wrong-headed hostility is a better sign than entire indifference, for the latter looks as though the church were outside the current of modern thought. If the church is to be anything more than the Boosters' Club of Zenith City there has got to be some hard thinking done by those at the head of it during the next twenty years. Somebody has got to seize hold of these new conceptions and point out their moral applications. Otherwise somebody else will make immoral applications of them.

"Unless the preacher gets accustomed to deep diving while he is young he is apt to swim shallower and shallower as he gets on in life. Unless he has thought things through for himself he will be at the mercy of every passing fad that blows. Theological schools ought to teach theology."

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